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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT,—the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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NEW ENGLAND WATER WORKS ASSOCIATION.

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THE MANAGEMENT OF THE TYPHOID FEVER EPIDEMIC AT WATERTOWN, N. Y., IN 1904.

BY GEORGE A. SOPER, PH.D., CONSULTING ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Read March 11, 1908.*]

Mr. President, Members of the Association, and Guests: Before taking up the subject of my paper, I hope the Association will allow me to express my thanks for its kind invitation to come here and tell about the Watertown epidemic. This epidemic may at first seem to be an old story. There is nothing new in the general idea of a typhoid epidemic caused by a public water supply derived from a badly polluted river, and if I had nothing more novel than merely that to relate I should not have come. But there were some features connected with the epidemic, and particularly with its sanitary management, which I believe will be new to you. On these questions particularly I shall welcome a free expression of your opinion.

There is no body before which an account of this kind could be presented to greater advantage, a statement which is warranted by the fact that the New England Water Works Association is composed of practical and scientific men, many of whom have had valuable experience with typhoid and keep themselves abreast of the best measures of avoiding it. It is generally recognized that New England is a source and center of inspiration in sanitary matters, and so far as the prevention of typhoid is concerned, this Association has done its full share to build up and maintain that good reputation.

The typhoid epidemic which is here described occurred in the first few months of 1904 at Watertown, N. Y. It was an uncommonly serious outbreak, numbering about one half as many cases as occurred in the epidemic at Ithaca the year before, and placed Watertown third among the cities of the United States which had typhoid death-rates in excess of 200 per 100 000 of population in the year 1904.

The typhoid history of Watertown for some years prior to this epidemic furnishes an example of the results which generally follow when a polluted river is used as a source of drinking water. The conditions of pollution were evident, but their significance was, apparently, not thoroughly appreciated until too late.

Perhaps the greatest interest which attaches to the epidemic lies in the energetic measures which were taken to stamp it out. If the city had seemed indifferent to the danger of typhoid, it certainly was anxious to make all possible amends when the inevitable catastrophe occurred.

As to the circumstances which led the city to continue for years to use the polluted river as a source of water supply, little has been said or written, so far as I am aware, and it is not my purpose to discuss this matter here. It is possible that indifference to the quality of the water was more apparent than real. The water works were in the hands of a municipal water board composed of citizens of the highest character and intelligence. They had sought and obtained expert sanitary advice on more than one occasion. There is reason to believe that the board was neither unmindful of the danger nor unwilling to take steps to remove it, but it appears that a decision as to the exact nature of the radical measures of protection needed could not, for some reason, be decided on.

The population of Watertown, according to an estimate made by the Census Bureau of the United States Department of Commerce and Labor, was 24 194 on January 1, 1904. The area of the city is somewhat over 3 000 acres; its assessed valuation of property exceeded $10 000 000. It is a manufacturing city, owing its prosperity largely to water-power developments on the Black River at this point. The location of Watertown with respect to the Black River is shown in Fig. 1.

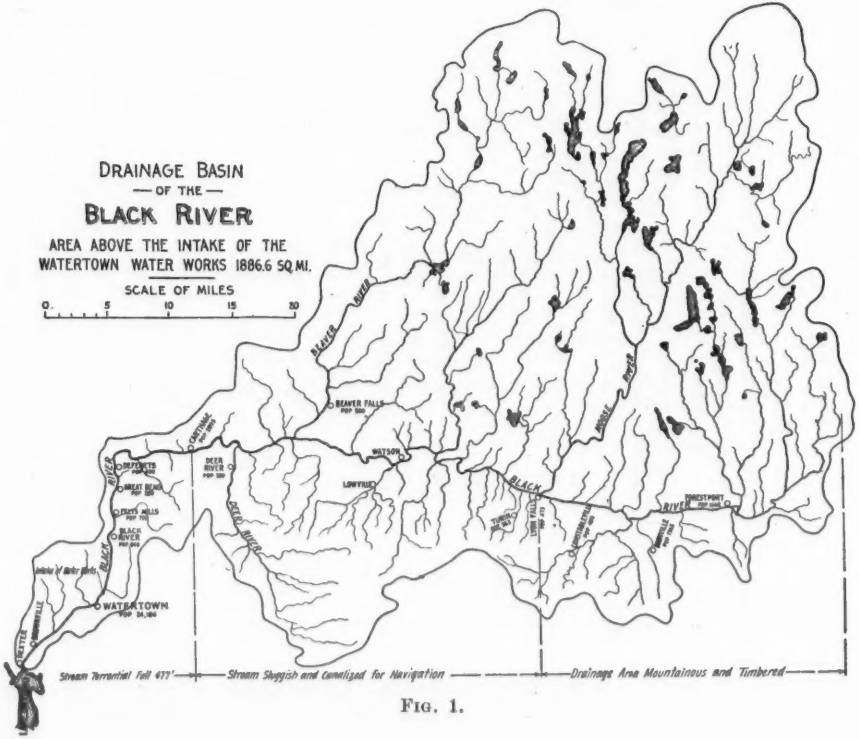

DRAINAGE BASIN
— OF THE —
BLACK RIVER
AREA ABOVE THE INTAKE OF THE
WATERTOWN WATER WORKS 1886.6 SQ.MI.
SCALE OF MILES
0 5 10 15 20
BEAVER FALLS
WATSON
LOWVILLE
BLACK RIVER
BEAVER RIVER
DEER RIVER
WATERTOWN
Stream Torrential Fall 477'
Stream Sluggish and Canalized for Navigation
Drainage Area Mountainous and Timbered

FIG. 1.

I.

PREVIOUS HISTORY OF TYPHOID AT WATERTOWN.

For many years typhoid fever had been unduly prevalent at Watertown, as is shown in Table I, in which the statistics for the city and state are given for twenty years.

TABLE I.

STATISTICS OF TYPHOID FEVER AT WATERTOWN, N. Y., FOR THE TWENTY YEARS 1885–1904.

Year.	Population.	Deaths from All Causes.	Deaths from Typhoid.	Per Cent. of Deaths from Typhoid to Deaths from All Causes.	Deaths from Typhoid per 100 000 Living.
1885	12 700	196	5	2.55	39
1886	13 100	229	5	2.18	38
1887	13 500	216	6	2.77	44
1888	13 900	296	8	2.70	58
1889	14 300	217	5	2.31	35
1890	14 700	234	7	2.99	47
1891	15 400	271	7	2.58	45
1892	16 100	376	12	3.19	74
1893	16 800	333	10	3.00	59
1894	17 500	323	15	4.61	85
1895	18 200	312	31	9.90	169
1896	18 900	331	11	3.32	58
1897	19 600	312	16	5.12	82
1898	20 300	340	22	6.47	108
1899	21 000	351	19	5.41	90
1900	21 000	397	24	6.04	110
1901	22 400	347	13	3.74	57
1902	23 200	317	16	5.04	69
1903	23 900	356	19	5.33	79
Average for Watertown for nineteen years,				4.17	71
Average for N. Y. state for same period,				1.3	25
For the epidemic year, 1904, at Watertown			47	12.81	194

NOTE. Since the epidemic the typhoid death-rate has been, per 100 000 of population, as follows: 1905, 24; 1906, 50; 1907, 37.

After 1894 there had been more typhoid than formerly. For the nine years preceding the epidemic of 1904 the average typhoid

death-rate had been 83 per 100 000 of population. The average for the whole state of New York for the twenty years prior to 1904 was 25, or less than one third that for Watertown. There had been, in the nine years previous to the epidemic, an average of 56 deaths from typhoid to 1 000 deaths from all causes in Watertown, while for the whole state, for the twenty-year period mentioned, the ratio had been 16 to 1 000. The records of the Board of Health show that typhoid existed at every season of the year, and that at various times it had been epidemic.

In 1895 two epidemics of typhoid occurred. One of these extended through April and May, and the other from August to December. The total number of deaths from typhoid fever in that year was more than twice that for the year preceding and three times that for the year which followed.

During the epidemic which occurred in the spring of 1895 suspicion centered upon the public water supply and the Board of Water Commissioners caused an investigation to be made to determine whether this was the source of the trouble. This investigation was made by the late Prof. Wyatt Johnston, the distinguished sanitarian, of McGill University, Montreal. The autumn epidemic was investigated by a committee of the Watertown Board of Health.

These two investigations, although made nearly ten years before the epidemic with which we are here chiefly concerned, throw such a strong light upon the conditions which led to the outbreak of 1904 that it seems desirable to pause for a moment to consider them.

The spring epidemic of 1895. The number of cases of typhoid which occurred in the spring epidemic of 1895 was, according to Professor Johnston's report to the Water Commissioners, 63. According to the records of the health office the number was 55. The Board of Health committee which investigated the epidemic which took place later in the year referred to the number in the spring outbreak as 80. The exact number cannot be ascertained, nor is it necessary that it should be. It is sufficient to note that an epidemic undoubtedly occurred in the spring of 1895.

Many circumstances led Dr. Johnston to suspect that the public water supply was the cause of the epidemic. Among fifty persons

suffering from typhoid fever, milk had been received from twenty-one peddlers, of whom only three had more than three cases on his route. The cases were distributed and not confined to any one section of the city. All of the patients had been regular drinkers of the public water supply. No one was ill who made it a regular practice to drink only boiled or filtered water. Most of the cases appeared after an unusual rise in the river; a freshet occurred between April 10 and 13, and most of the cases were recognized between April 20 and May 1.

The net result of Dr. Johnston's investigation was the opinion that the epidemic had come from the water supply. The supply had become infested with typhoid germs, in his judgment, from people in the many mills and other buildings which existed on the Black River above Watertown. He pointed out that unless these sources of pollution were remedied, typhoid fever would continue to be prevalent in Watertown and epidemics would occur from time to time. The danger to public health lay not in the volume of refuse which entered the stream, but in its quality; a large amount of factory drainage was far less liable to lead to disease than a small amount of sewage from water closets or the contents of privies. The existence of many possible points of pollution prevented the Black River from being regarded as a source of safe drinking water at Watertown unless the water was purified.

Dr. Johnston recommended the consideration of a plan for filtering the water, and advised that, pending such purification, a thorough inspection be made of the watershed, followed by the removal of all sources of direct pollution, especially privies, and the rigid suppression of nuisances in the neighborhood of the intake. Finally, he recommended that the intake be moved so as to be less liable to receive water from a polluted brook which entered the river nearby, and farther from the drainage of a neighboring cemetery.

Some of these recommendations were carried out, as we shall see later on. It was impossible, however, to remove the sources of pollution, "especially privies," which, as it will also appear, increased greatly in number as the Black River above Watertown was developed for mill purposes in succeeding years.

The second epidemic of 1895. According to the report of the

committee of the Board of Health which investigated the second epidemic of 1895 there were, in this latter outbreak, 180 persons attacked. Thirty-seven cases were accounted for on the theory that in September the milk supply of one of the numerous milk peddlers in Watertown became contaminated. The other cases were believed to have been caused by a contamination of the public water supply. The worst sources of pollution of the Black River were carefully described and mapped by Messrs. Boyer and Armstrong for this committee.

In concluding their report the committee recommended that the water supply be protected against the pollution which had, on two separate and recent occasions, caused much sickness and death in the city. The cases are reported to have occurred as follows: August, 56; September, 30; October, 63; November, 20; December, 12.

II.

THE PUBLIC WATER SUPPLY FROM THE BLACK RIVER.

The Water Works.

The drinking water supply of Watertown is taken from the Black River at a point about two miles about the city, as shown in Fig. 2. Here there is an arm of the river which has been dammed off from the main stream, making a stretch of quiet water about three quarters of a mile long, from two hundred to six hundred feet wide, and something less than eight feet deep. This is called the settling basin, and from its lower end the water for the city is drawn. The dam failed and was destroyed in December, 1901. It was rebuilt in 1902.

From a pumping station on the river bank the water was, at the time of the epidemic of 1904, pumped to a reservoir situated at an elevation of about 150 feet above the level of the stream. From here it flowed to the consumers by gravity. The reservoir capacity was about 5 000 000 gallons and the average daily consumption about 4 000 000 gallons. Theoretically, water taken in at the pumps should reach the majority of consumers within forty-eight hours.

No irregularity in the operation of the plant occurred after the dam forming the settling basin failed in 1901. A plant of rapid

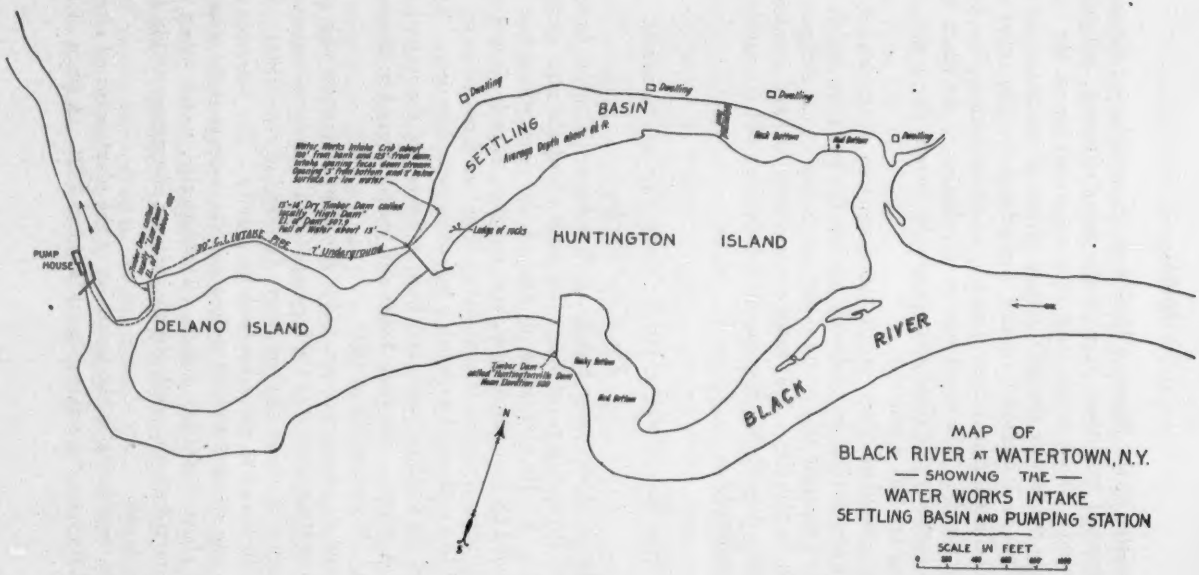

Dwelling
Dwelling
Dwelling
SETTLING
BASIN
Average Depth about 6ft.
Rock Bottom
Mud Bottom
Dwelling
Water Works Intake Crib about
100' from bank and 125' from dam.
Intake opening faces down stream.
Covered 5' Pure bottom and 7' below
Surface at low water
15'-16' Dry Timber Dam called
locally "Intake Dam"
11' of Dam only
Wall of Water about 15'
Ledge of rocks
HUNTINGTON ISLAND
PUMP HOUSE
30" C.I. INTAKE PIPE
7' Underground
DELANO ISLAND
Timber Dam
called "Huntingtonville Dam"
Mean Elevation 328
Rocky Bottom
Mud Bottom
BLACK RIVER
N
MAP OF
BLACK RIVER AT WATERTOWN, N.Y.
— SHOWING THE —
WATER WORKS INTAKE
SETTLING BASIN AND PUMPING STATION
SCALE IN FEET
0 200 400 600 800 1000

FIG. 2.

filters, designed by Allen Hazen, was begun in the autumn of 1903, and has been in service at the pumping station since the fall of 1904.

Quality of the Water.

The water of the Black River is naturally clear but colored with vegetable matter from the forests of the Adirondacks. It is soft and remarkably free from mineral matter except for a small amount due to mill drainage.

The quality of the water is likely to change rapidly with the changes which take place in the volume of the flow of the river. The flow varies from about 600 cubic feet per second to 18 000 cubic feet per second. The turbidity seldom rises above 200 parts per million as measured by the silica scale, and is usually very much lower than this figure. The water is improved somewhat in quality by passing through the sedimentation basin, but such figures as are at hand do not indicate that there is often a reduction exceeding about 50 per cent. in the numbers of bacteria. The chlorine in the river water is well above 0.3 parts per million, which is the normal in this vicinity. Presumptive tests for coli indicate fairly well the polluted condition of the river. Many analyses of the water have been made in connection with the operation of the filter plant, which was put in operation subsequent to the epidemic, but I am indebted to Mr. Francis F. Longley, who was for a time in charge of the operation of these works, for my information concerning this matter. Table II shows the results of some of Mr. Longley's chemical analyses.

TABLE II.

RESULTS OF CHEMICAL ANALYSES OF BLACK RIVER WATER.

(Parts per million.)

Date.	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Chlorine.
October 4, 1904	0.186	0.030	0.001	0.15	0.90
November 2, „	0.112	0.012	0.001	0.05	1.05
November 28, „	0.074	0.002	0.002	0.10	1.20
December 18, „	0.092	0.020	0.002	0.05	0.90
January 9, 1905	0.116	0.014	0.003	0.10	1.00
February 10, „	0.078	0.006	0.001	0.25	1.25
February 28, „	0.072	0.006	0.001	0.15	1.15
March 20, „	0.216	0.128	0.003	0.20	1.10

So far as I am aware, no analyses of Black River water were made which adequately show the condition of the Watertown supply immediately before or during the epidemic. One sample was taken through the ice near the intake on February 15 and sent for analysis to Dr. R. M. Pearce, of the Bender Hygienic Laboratory at Albany. Dr. Pearce reported that this sample gave 14 200 bacteria per cubic centimeter on gelatine, and 280 on agar. The bacteria liquefied the gelatine with a "moderate putrefactive odor." Gas of the type characteristic of the colon bacillus was found.

The analysis shown in Table III, made by Mr. Longley during rises in the river one year later, perhaps give some idea of the conditions.

TABLE III.

RESULTS OF ANALYSES FOR BACILLUS COLI COMMUNIS IN WATER FROM THE INTAKE OF THE WATERTOWN WATER WORKS.

(By the word "gas" is meant 20 per cent. or more gas in dextrose broth.)

Month.	Average Discharge of River in Cu. Ft. per Second.	Results of Analyses.			
		Number Samples Examined.	Per Cent. Samples of 0.1 c.c. showing Gas.	Per Cent. Samples of 1.0 c.c. showing Gas.	Per Cent. Samples of 10 c.c. showing Gas.
October, 1904	4 700	11	9	91	100
November, "	1 920	18	33	100	100
December, "	1 650	20	35	95	100
January, 1905	2 640	17	47	100	100
February, "	2 380	15	20	93	100
March, "	4 010	20	50	90	100
April, "	11 350	15	27	80	100
May 1–10, "	6 905	6	0	66	100
		122	32	92	100

Physical characteristics of the Black River. The Black River rises in the heart of the Adirondacks, flows in an irregular, southwesterly direction, and empties into Lake Ontario. The distance from the mouth of the stream to the head of its principal tributary is 132 miles. Its total drainage area as given by the Report of the Board of Engineers on Deep Waterways, is 1903.2 square miles. The drainage area with some of the larger villages is shown in

FIG. 1. Intake of the Watertown Water Works, showing the Supply Main in the Foreground.

FIG. 2. Pump House of Watertown Water Works.

Fig. 1. The area above the intake of the water works is given by the same authority as 1 886.6 square miles.

The drainage area may be divided into two parts: a sparsely populated catchment area, which lies almost exclusively in the Adirondack Mountains, and a much more thickly populated, steep, narrow valley from Carthage, past Watertown to Lake Ontario. Parts of the upper portion of this catchment area have a rapid fall which sends down the waters from the rains and melting snows rapidly. In the distance of twenty miles from Carthage to Lake Ontario there is a fall of 477 feet. Through this valley the river flows in a turbulent and sometimes destructive manner. A large amount of the power due to the fall has been developed and is utilized by mills.

In 1902 there were on the drainage area of the Black River and its tributaries, according to the report of the New York State Water Storage Commission of 1903, forty-four dams, furnishing an aggregate of 76 000 horse-power to mills situated on the streams. The value of these mills was estimated at $12 302 100 and the annual value of their product at $15 101 440. There were 5 349 hands employed. Many of these mills were situated at Watertown, but, as will be seen presently, there were several villages along the Black River between Watertown and Carthage where mills, factories, and dwellings crowded the banks. There were a few mills beyond Carthage, at Lyon Falls, and elsewhere.

Sanitary condition of the Black River above Watertown. Through the coöperation of the Watertown Board of Health and the Water Commissioners of the city a careful sanitary inspection was made in 1895 of the shores of the Black River from Watertown to Carthage, a distance of seventeen miles. In this distance there were four villages which, with isolated country houses, had an aggregate population of over five thousand persons. Sketches of a few of these villages as they existed in 1895 are shown in Fig. 3. It appears, upon reliable testimony, that the population in this district had increased about fifty per cent. by 1904. An entirely new village, with a population of between four and five hundred persons, had grown up about a large paper mill at Deferiets, about ten miles above Watertown. To accommodate these people a sewerage system had been built to carry their sewage to the river.

In fact, sewage and other drainage entered from all the villages and mills without any restriction.

In the territory between Watertown and Carthage there were, in 1895, 165 buildings which drained into the stream. There were

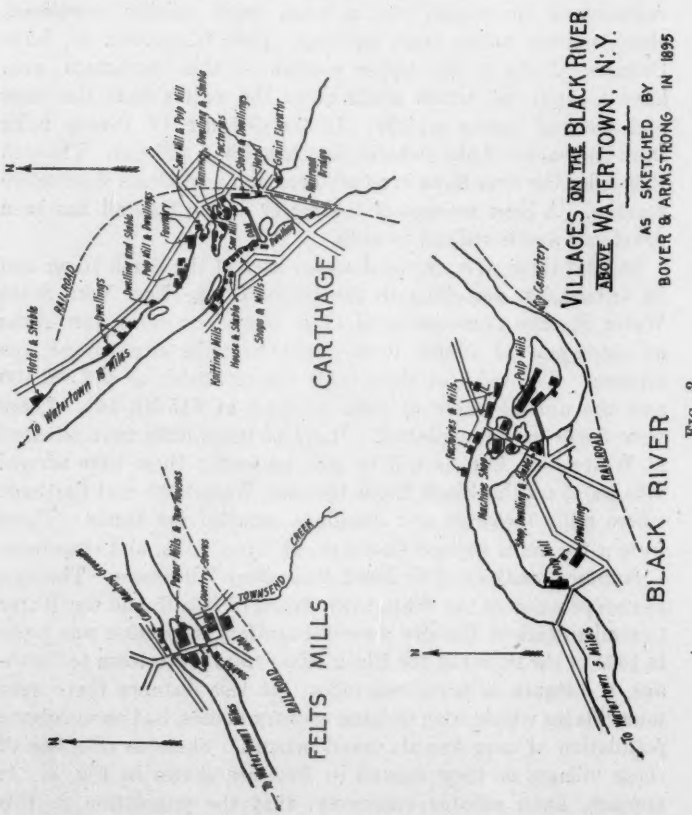


FIG. 3.

82 privies, 17 stables for horses, cattle, and hogs, 10 paper mills, 4 stores, 3 hotels, 2 bakeries. 15 shops of different kinds, and 5 other buildings used for different purposes. The 82 privies were used by about 740 persons and were located directly over the stream, or on its bank, and discharged their contents into the river.

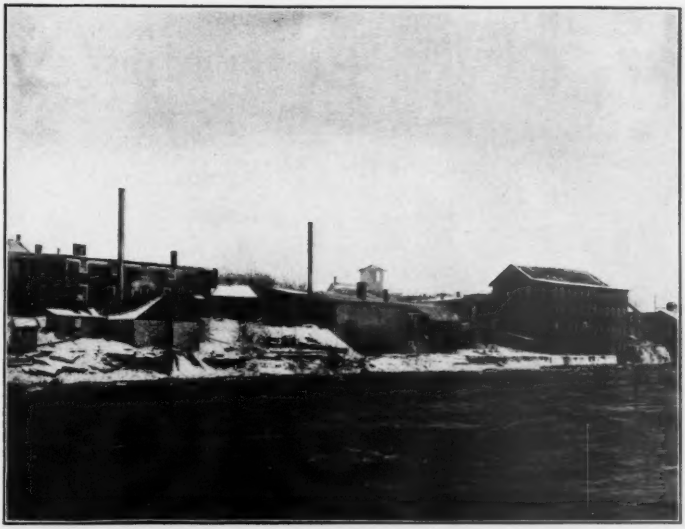


FIG. 1. Town of Black River, looking from the South Side of the Stream. This is five miles above the intake of the Watertown Water Works.

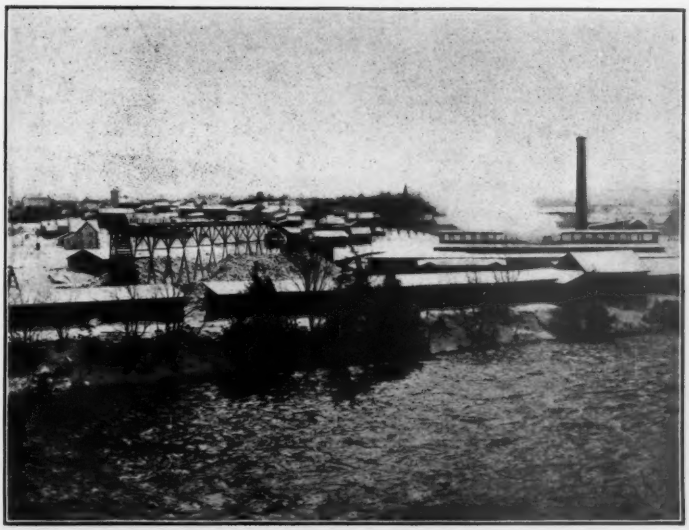


FIG. 2. Felts Mills, Seven Miles above the Intake of the Watertown Water Works.

The manure from the 17 stables was either thrown into the river or piled upon the bank, whence it drained into the stream. In addition to the 740 people whose excreta ordinarily passed directly into the river, about 6 000 to 7 000 people from different parts of the country attended annually a camp meeting held on the banks of the stream at Felt's Mills, seven miles above the intake of the Watertown water works. At this point four privies stood directly on the slope of the bank.

FIG. 4. Distribution of Typhoid Deaths through the Year in Watertown and New York State. The Distribution in the United States corresponds closely with that in New York State. The Peculiarities of the Watertown Curve suggest that the River Water has been a Leading Cause of Typhoid.

It seems unnecessary to point out the danger which these insanitary conditions represented. Aside from the probability that cases of typhoid fever existed every year among the persons who used the privies and sewers, not to mention persons who were chronic bacillus producers, the river was made the disposal place of refuse of every kind. Manure entered it from stables. It is well known that the manure of stables commonly contains human dejecta. It should also be remembered that when typhoid fever occurs in the country, it is usual to throw the stools and urine down the banks of the nearest stream to get rid of it. The Black River was, then, a very dangerous stream from which to take drinking water.

Ineffectiveness of State rules adopted for the protection of the Black River water supply. At the request of the Water Commissioners of Watertown, the State Board of Health, in 1896, formulated rules for the protection of the waters of the Black River from pollution above the intake of the water supply of the city of Watertown. These rules and regulations were made in virtue of Section 70 of Chapter 661 of the state laws of 1893, which empower the State Board of Health "to make rules and regulations for the protection from contamination of any or all public supplies of potable waters and their sources within the state" and "to impose penalties for the violation thereof and the non-compliance therewith."

As is the custom in New York state, the rules were published for six weeks in the principal papers of the district, in this case at Watertown, Carthage, and Lowville, and a certificate to this effect, together with a certified copy of the rules, having been filed in the office of the county clerk of Jefferson County, on April 30, 1896, the rules became law.

The Water Commissioners of Watertown thereafter had the legal right to insist that all dangerous pollution be kept out of the Black River above Watertown. But, as another provision of the public health law compelled the commissioners to bear the expense which this work incurred and also to make good any financial loss to mills and villages which might result, the cost of enforcing the regulations made protection of the water supply in this manner seem impracticable. The law was not enforced.

FIG. 1. Great Bend, from the North Side of the Stream. This is about eight miles above the intake of the Watertown Water Works.

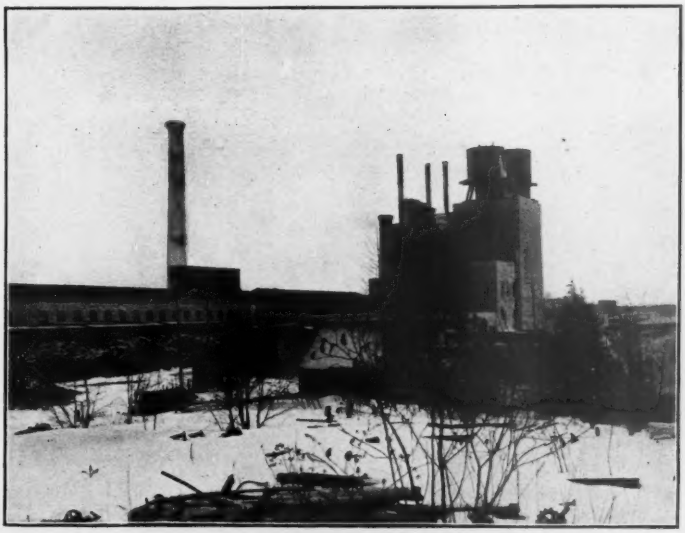


FIG. 2. Deferiets, Ten Miles above the Intake of the Watertown Water Works. A sewer empties into the Black River at this point.

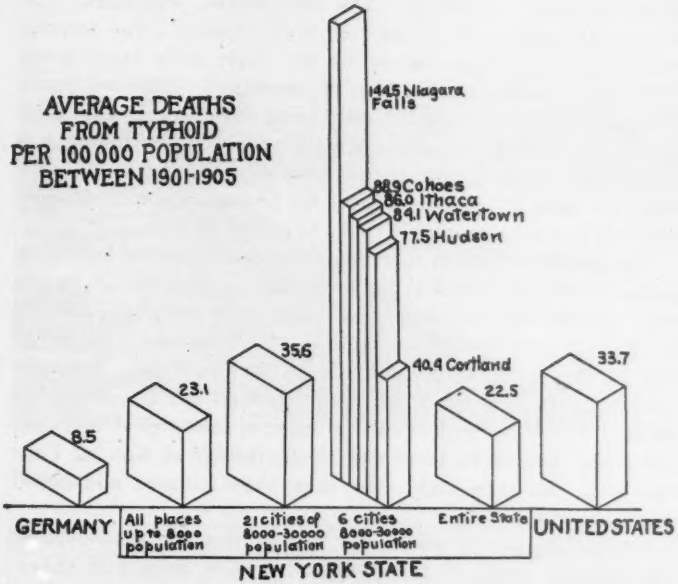


FIG. 5. Comparison between Typhoid Death-Rates for Germany, New York State, and United States. Also rates for six small cities in New York as compared with twenty-one other cities of the same in class New York State. The prevalence of typhoid at Watertown is thus made evident.

III.

THE EPIDEMIC OF 1904.

A study of the weather conditions preceding the epidemic of 1904 discloses some matters of particular interest.

The Weather.

To begin with, in the month of October, 1903, there were excessively heavy rains. These were followed by a long term of cold weather: the November of 1903 was decidedly colder than the average November. After the 18th of November the maximum daily temperature on the drainage area of the Black River was

generally below 32 degrees. The precipitation was light. The weather through most of the month of December was severely cold, the average temperature for the whole state being lower than for any similar period since the records of the United States Weather Bureau were begun. According to the Climate and Crop Service of the United States Weather Bureau, the ground was frozen and covered with snow throughout the month. In the drainage basin of the Black River an unusual amount of snow fell even for that remarkably cold and snowy section.

The intense cold which characterized the early part of December abated for nearly a week in the latter part of the month. Beginning with the 20th, the temperature rose every day above freezing at Lowville until the 26th. On the 20th there was a fall of .73 inch of rain at Lowville and .85 at Number Four. This was accompanied by a warm south wind. In the five days, December 20–24, 1.5 inches of rain, or its equivalent of snow, fell at Lowville, and in the three days, December 19–21, the fall at Number Four was 1.31. An excessively cold snap then followed and lasted throughout the month.

A large amount of water was washed from the snow-covered hillsides and banks of the streams by these rains and thaws. Sewers were flushed and ice in the vicinity of the sewer outlets was melted and carried off. According to records made by the Division of Hydrography of the United States Geological Survey, the discharge of the Black River at Felt's Mills, seven miles above Watertown, rose from about December 20. The rise was rapid and continuous until December 25, after which the flow diminished with slight remissions until January 9, 1904.

The source of the infectious matter. About a month after the outbreak of the epidemic, there were sent out a number of inspectors to determine, if possible, whether any cases of fever had occurred which could have led to the contamination of the water supply with typhoid germs. The search extended along the banks of the Black River as far as Carthage. One of the inspectors, Mr. W. E. Fuller, in a communication to *Engineering News*, March 3, 1904, page 205, has recorded what was found up to the latter part of February, 1904.

Going up stream from Watertown, the nearest cases of typhoid

FIG. 1. Carthage, from the West Side of the River.

FIG. 2. West Carthage, from Carthage. A sewer discharges under the further end of the bridge. This is eighteen miles above the intake of the Watertown Water Works.

were found at Black River, about 4½ miles above the intake of the water works. Five cases existed there: the first started during the latter part of December and the other four began in the first half of January, 1904.

No cases of typhoid were found in the next two villages, Great Bend and Felt's Mills.

At Deferiets, where there was a sewerage system emptying into the river about 10 miles above the intake of the Watertown water works, there was a small epidemic of typhoid at about this time. One case had occurred in September, 1903, a second in the first half of December, two more in the second half of December, and twelve in January and February. Deferiets has a population of about 500.

At the twin villages of Carthage and West Carthage, about seventeen miles above the water works, fifteen or sixteen cases of typhoid were said to have occurred from September to February. These villages are not provided with public sewers, although several private sewers empty into the river.

It thus appears that typhoid had existed at more than one of the villages between Watertown and Carthage before the outbreak at Watertown. How far typhoid had been prevalent in the thirty or forty settlements or villages on the drainage area above Carthage is not, and never will be, known.

Apparently there was within this watershed what has occurred in many other river valleys,— an epidemiological wave of typhoid. It is not difficult to understand how these waves occur. When typhoid is introduced at any point, the infectious matter gets into the water courses, which are, of course, the natural sewers of the country. As the sewers of one town become the water supplies of others, the disease is transmitted by the water down the valley in the direction of the flow of the stream. To some extent there is also an upward, downward, and lateral transmission of the disease, due to movements of the population and the transportation of milk from one village to another.

With a whole valley infected with typhoid, as was the valley of the Black River at the time of the Watertown epidemic, it is plain that the lower parts of the river are likely to become very heavily contaminated with typhoid germs and, owing to the numerous

points of pollution, may remain so for a long time. We have under these circumstances not an example of a sudden, intense, and brief contamination such as produce the most sensational explosions of typhoid, but a more continuously operating cause and a corresponding continuous effect. Instances of epidemics of this type have frequently been afforded by cities which draw their water supplies from large rivers. The statistics of the Watertown epidemic, although admittedly imperfect, seem to indicate that the public water supply of the city may have been contaminated in this manner.

Judging from the fact that many cases of typhoid occurred at Black River and Deferiets at about the time that the epidemic began at Watertown, it is barely possible that there was one large common source of germs which supplied all these places. In other

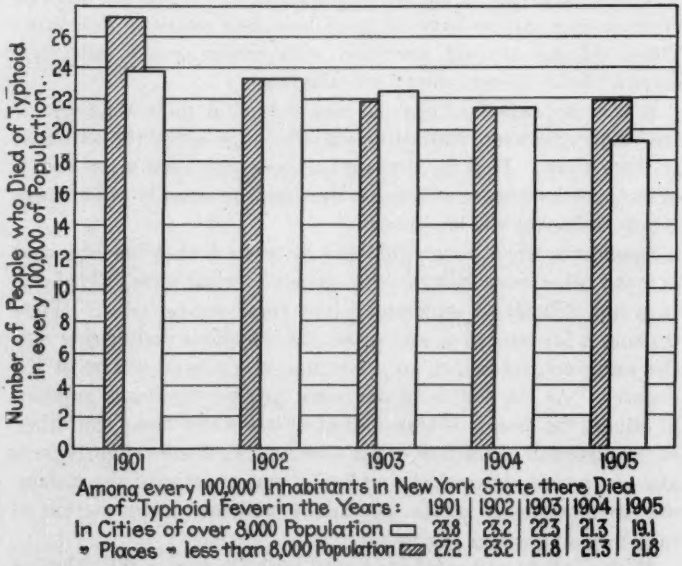


FIG. 6. Comparison between Rural and Urban Typhoid Death-Rates in New York State for Five Years, showing that in the year of the Watertown epidemic, typhoid was not unusually prevalent in city or country districts.

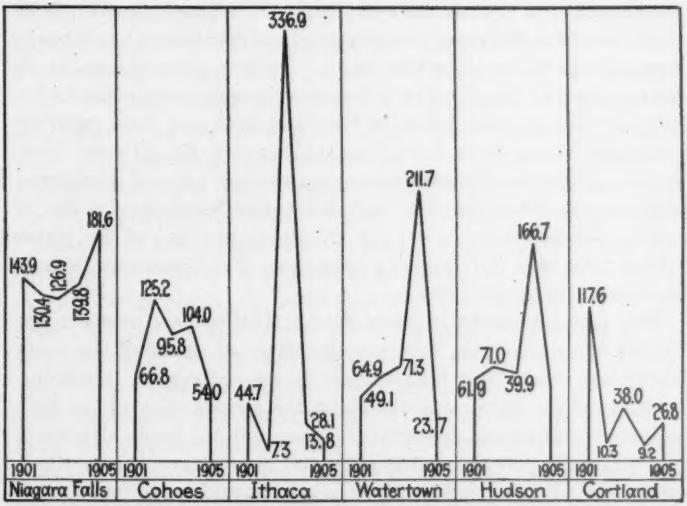


FIG. 7. Comparison between the Records of the Six Cities in New York State which had the Greatest Number of Deaths from Typhoid between the Years 1901 and 1906. According to the average rate, Watertown occupied fourth place; according to the rate for each year, Watertown was second.

words, it may be that the infectious matter which caused the Watertown epidemic originated above both Deferiets and Black River.

On the other hand, the germs which produced the Watertown outbreak may have come exclusively from some nearby point, such as Deferiets.

Setting aside this interesting but uncertain element as to the exact origin of the germs, the fact is clear that the epidemic at Watertown came from the public water supply.

The outbreak and course of the epidemic of 1904. According to the testimony of physicians, there had been an unusual amount of diarrheal disease in Watertown during the fall and early winter of 1903–4. During November and December typhoid fever had been much less prevalent than usual at this season of year. From

the reports of physicians made to Dr. E. S. Willard, health officer of the Board of Health of Watertown, it appears that the number of cases of typhoid for November was 7. In December the number reported was 15. On January 1, 8 cases were reported, and on the 2d, 13. In the following few days the number of new cases reported each day varied from 1 to 13. On January 15, 23 cases were reported. The newspapers now announced an unusual prevalence of typhoid, and, suspecting that the public water supply was to blame, the people were advised by the mayor to boil the water which they used for drinking purposes. The cases were widely scattered through the city.

The daily incidence of cases during the first few weeks is not clearly known, nor in fact are the dates of onset of the cases accurately established for any part of the outbreak. It was not customary for physicians to report their cases of typhoid with regularity before the epidemic and they did not do so afterward.

To a sanitarian unfamiliar with the peculiar conditions which occur in typhoid epidemics the failure of physicians to report their cases seems inexplicable if not inexcusable. The fact is, however, that physicians are extremely busy at such times in attending to the pressing needs of the sick, and are sometimes called upon to spend so much time in ministering to their patients that they feel unable to allow themselves proper time for sleep or meals. Often several visits are necessary before the nature of the sickness can be discovered. When a patient is at last found to be suffering from typhoid the date of onset may be forgotten. The full name and exact address of each patient is rarely known to an attending physician. To expect that every case of typhoid will be promptly and satisfactorily reported, therefore, is unreasonable, however desirable such reports may be from the public health standpoint. For a board of health to get even fairly satisfactory returns generally requires much telephoning, interviewing, and circularizing and sometimes a house-to-house canvass.

After the board of health work became systematized, each case reported was tabulated on two sets of cards. One of these sets was then arranged alphabetically according to the names of the patients and one set according to the street addresses. The sanitary circumstances surrounding each case were carefully inves-

tigated by the Board of Health and records kept of the principal points of information ascertained in connection with it. Many errors in the returns were corrected in this way. The genuine cases of typhoid were finally spotted on a large wall map and placed on a chart. In the stress of the hour some cases were probably overlooked by the physicians and the exact dates of others accidentally misstated. Some cases were reported several times and the addresses were frequently wrong. Some cases of disease other than typhoid were reported as typhoid. A curve plotted from the corrected returns in the possession of the Board of Health shows, as such curves always do, large numbers on some days and almost none on days immediately preceding and succeeding these. It is practically certain that people do not fall sick during typhoid epidemics in this extremely irregular way.

In the hope of eliminating some of the errors in the records, I have taken as an approximation to the probable number of cases each day an average of the number of cases for three days — the day before, the day itself, and the day after the date on which the number of cases is desired. The corrected returns and these averages with averages for each five days are given in Table IV. From these data I have plotted curves to give some idea of the progress of the epidemic. (See Fig. 8.)

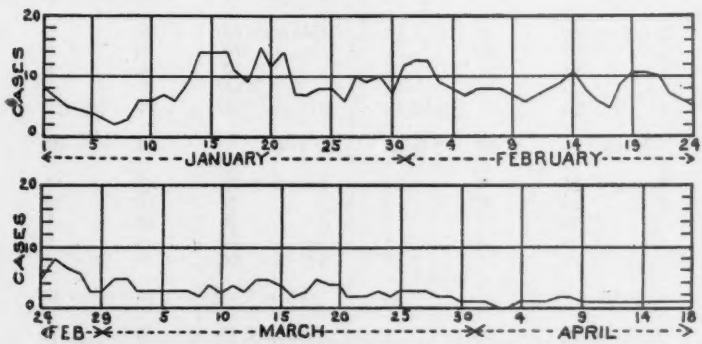


FIG. 8. Progress of the Epidemic of 1904. The Board of Health campaign was started about February 22. The upper curve represents the course of the epidemic before, and lower curve its course after, the repressive measures were put in force.

TABLE IV.

CASES OF TYPHOID FEVER AT WATERTOWN, N. Y., FROM JANUARY 1, 1904, TO APRIL 18, 1904.

Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904			1904		
January 1	8	10	January 31	6	12
" 2	13	7	February 1	22	13
" 3	0	5	" 2	10	13
" 4	1	1	" 3	8	9
" 5	2	2	" 4	8	8
Total	24	25	Total	54	55
January 6	3	3	February 5	9	7
" 7	3	2	" 6	4	8
" 8	1	3	" 7	12	8
" 9	4	6	" 8	7	8
" 10	13	6	" 9	5	7
Total	24	20	Total	37	38
January 11	1	7	February 10	8	6
" 12	7	6	" 11	5	7
" 13	10	9	" 12	9	8
" 14	9	14	" 13	9	9
" 15	23	14	" 14	10	11
Total	50	50	Total	41	41
January 16	9	14	February 15	13	8
" 17	10	11	" 16	1	6
" 18	14	9	" 17	5	5
" 19	4	15	" 18	9	9
" 20	26	12	" 19	12	11
Total	63	61	Total	40	39
January 21	7	14	February 20	13	11
" 22	8	7	" 21	7	10
" 23	5	7	" 22	10	7
" 24	8	8	" 23	3	6
" 25	11	8	" 24	6	5
Total	39	44	Total	39	39
January 26	6	6	February 25	6	8
" 27	8	10	" 26	12	7
" 28	15	9	" 27	3	6
" 29	5	10	" 28	3	3
" 30	10	7	" 29	3	3
Total	44	42	Total	27	27

TABLE IV.—*Continued.*

Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904			1904		
March 1	8	5	March 26	5	3
" 2	5	5	" 27	2	3
" 3	2	3	" 28	3	2
" 4	2	3	" 29	1	2
" 5	4	3	" 30	1	1
Total	21	19	Total	12	11
March 6	4	3	March 31	2	1
" 7	2	3	April 1	0	1
" 8	3	2	" 2	0	0
" 9	2	4	" 3	1	0
" 10	6	3	" 4	1	1
Total	17	15	Total	4	3
March 11	1	4	April 5	0	1
" 12	4	3	" 6	1	1
" 13	3	5	" 7	2	2
" 14	8	5	" 8	2	2
" 15	3	4	" 9	1	1
Total	19	21	Total	6	7
March 16	0	2	April 10	0	1
" 17	3	3	" 11	2	1
" 18	4	5	" 12	0	1
" 19	7	4	" 13	0	1
" 20	2	4	" 14	2	1
Total	16	18	Total	4	5
March 21	2	2	April 15	0	1
" 22	2	2	" 16	0	1
" 23	3	3	" 17	2	1
" 24	3	2	" 18	1	1
" 25	1	3	Total	3	4
Total	11	12	Grand total,		595

There is little doubt that the epidemic broke out about January 1, although it was not investigated until over a month later. The daily increase in the number of cases was apparently rapid up to about January 20, when there was a slight decrease until the 25th,

followed by another increase which lasted until about Feburary 1. The daily number of cases then declined slowly and remained comparativelv constant between February 9 and 25. After this there was a considerable reduction. The epidemic may be considered to have ended April 18. It had run 110 days.

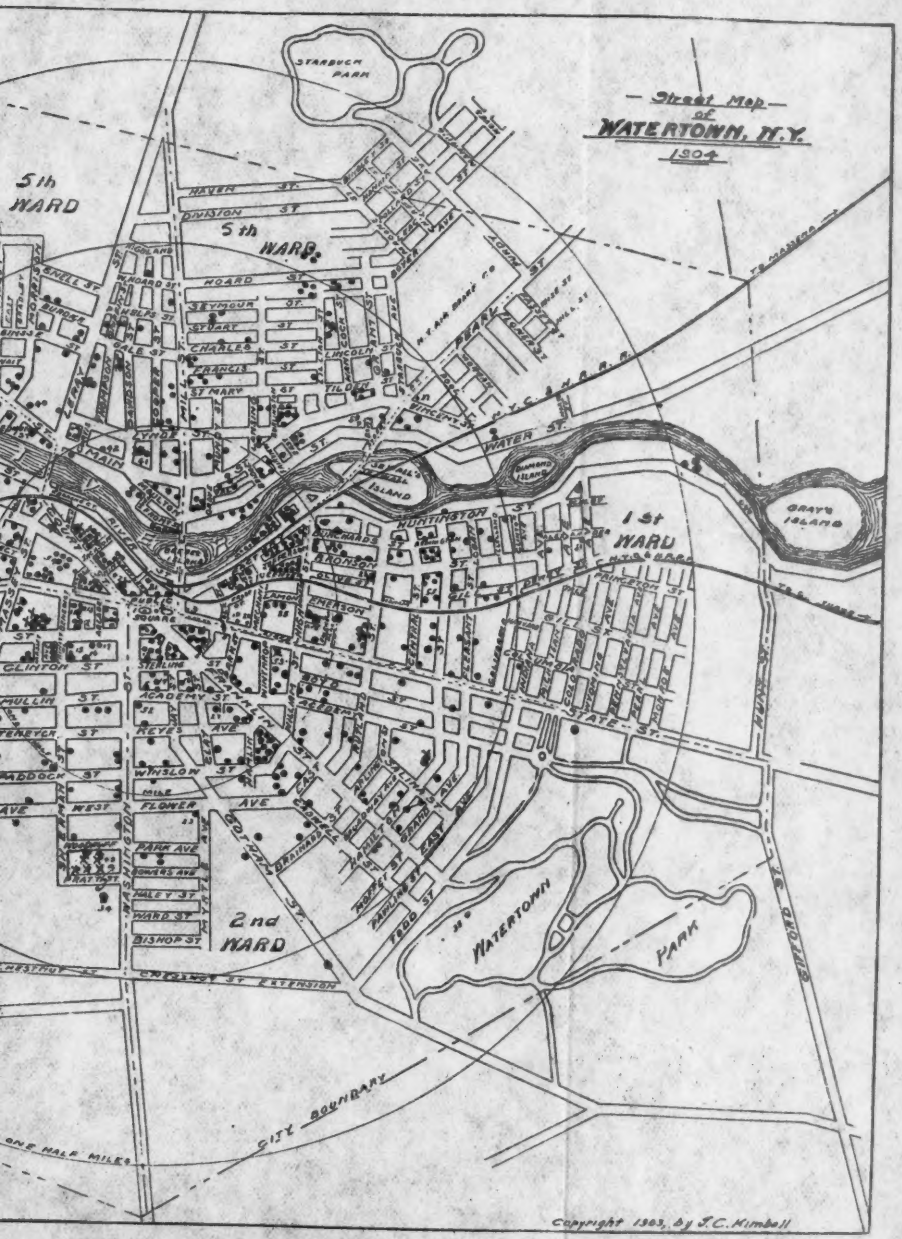
The total number of cases of which I have reliable record was 595. The number of deaths to May 1 was 44. The case fatality, based on these figures, was 7.4 per cent.

Subsequent to April 18, 102 cases were reported up to January 1, 1905. The number of deaths from typhoid, in addition to those already mentioned, was 3 up to January 1, 1905. Since 1904 the number of cases and deaths from typhoid reported at Watertown have been as follows: 1905, 108 cases, 6 deaths; 1906, 130 cases, 13 deaths; 1907, 103 cases, 10 deaths.

When the cases of typhoid were spotted on a map it was seen that the fever had visited every part of the city. (See Plate V.) The poorer sections suffered most, and the aristocratic parts least, a result which was largely accounted for by the fact that the poorer sections were the most crowded and there were consequently more people to be attacked in a poor section on a given area. In the best residential quarters, also, more personal care was exercised to avoid the fever. The drinking water of many of the people was boiled or carefully filtered. Institutions, such as children's homes, and the jail, had their full share of typhoid.

There were some parts of the city which suffered to a greater extent than could be fully explained on the score of crowding and lack of personal precautions, and it seemed reasonable to conclude that some peculiarity of the distribution system of the water supply carried to these sections exceptionally large doses of infectious matter, or that insanitary conditions about the houses increased the people's chances of infection. No extensive local foci such as germ-infested wells were found, such as I had discovered at Ithaca. The people, as a rule, were in much better financial circumstances and lived more comfortably and there was much less typhoid transmitted from person to person than I had seen in the epidemic at Butler. Nevertheless, the fever was undoubtedly transmitted to some extent from person to person in spite of the utmost efforts of the Board of Health. The greatest danger in

Dots show Location of Typh



yphoid Cases; Crosses show Location of Erysipelas Cases.

this regard probably occurred when a patient was nursed at home. Under these circumstances the person who acted as nurse sometimes did the cooking for the rest of the family and, for convenience and warmth, the patient was occasionally nursed in a room close to the kitchen. As far as practicable these dangers were reduced to a minimum by the operations of the Board of Health.

IV.

MEASURES TAKEN TO CHECK THE EPIDEMIC.

At a meeting of the local Board of Health, held on February 1, it was decided to make an official investigation into the cause of the outbreak. It was fully realized that a serious epidemic was at hand. The health officer had notified the State Department of Health of the prevalence of typhoid under date of January 30.

State Action. On February 8 the health officer was empowered "to employ a sanitary expert at once to investigate the situation and take such measures as may be reasonable and necessary to eliminate the epidemic." In response to the information furnished the State Department of Health on January 30, Prof. Olin H. Landreth, consulting engineer of the State Department of Health, made the city a visit on February 13.

Professor Landreth caused a canvass to be made to ascertain the number and distribution of the cases and the date of attack in each case. He also advised that postal cards be sent to every family in the city, cautioning the people to boil the water used for drinking, for washing vegetables which were to be eaten uncooked, and for washing dishes, etc. Professor Landreth's suspicion rested upon the public water supply as the cause of the outbreak and he appointed canvassers to visit the settlements and shores along the Black River to search for any cause of typhoid which might have led to the contamination of the public water supply. At the same time data were collected which put the milk supplies out of question as the cause of the epidemic.

On February 20 Professor Landreth again visited Watertown. On this occasion the investigation which he initiated on his former visit was supplemented. Various sanitary measures were recommended and much salutary advice was given on sanitary matters.

Steps were begun toward cleaning and disinfecting all premises on the Black River where typhoid fever cases were found to have existed.

Other short visits were subsequently made to Watertown by Professor Landreth in his official capacity. On these occasions the need of extending the inspection and disinfecting work on the Black River drainage area were urged. But the city was less interested in cleaning up the drainage area than in attending to sanitary work within its boundaries. Eventually, by mutual consent, the direction of the work on the drainage area was placed wholly in Professor Landreth's hands, the city of Watertown agreeing to coöperate with the State Department of Health to the extent of paying the cost of this work.

Unable to secure from the state an expert who could give his undivided time to the work of checking the epidemic, and believing that the situation required such attention, the Board of Health engaged me for this purpose.

Plan of the campaign carried on by the city. A sanitary campaign was planned with the double object of checking the epidemic and restoring public confidence. Much of the work was based on my experience in the typhoid epidemic at Ithaca, N. Y., where I acted as the official representative of the State Board of Health and initiated through the local Board of Health an active campaign against the fever. I had been called to the Ithaca work, apparently, because I had had some experience with typhoid when I was the sanitary engineer of the New York City Department of Health.

The measures for controlling the epidemic which were carried out at Watertown during my connection with the city were largely based on the results of Koch's now famous studies at Trier, and the opinion which had grown out of my experience, that typhoid is not only infectious, but contagious, and transmissible from person to person.

The immediate objects of the campaign were the prevention of infection through the river water and from cases of typhoid already in the city. It was accepted by me as abundantly proved that the water supply had given rise to the original cases.

I advised that every typhoid patient be sent to hospital or

strictly isolated at home. No patient should be discharged from medical care until bacteriological tests showed that his excretions were no longer dangerous. All mild and suspicious cases of fever should be treated like typhoid. Secondary sources of disease, such as contaminated wells and milk supplies, were to be guarded against. All infectious matter should be destroyed by disinfection at its source. It was not practicable to put all these measures into effect; at least, not at once; nor ever with that completeness which was desirable. They were, nevertheless, kept always in mind and give the key to the principal work which was done by the Board of Health during my connection with it.

The sanitary work of the inspectors acting under the direction of the State Department of Health on the drainage area of the Black River and the natural flow of the river during two months of time seemed to me to have been sufficient to have removed every source of danger from the public water supply which it was practicable to remove. Still, in order to obtain the greatest measure of safety procurable, various steps were taken to secure protection from the public water supply. The distributing mains were flushed from the hydrants, one section of the city being taken at a time, and the work done in a thorough manner. The people were urged to continue to boil that portion of the water which it was necessary to use for drinking, dish-washing, and other purposes which might, by any possibility, lead to infection. The builders of the filtration plant were requested to push the completion of their work so that the plant could be made available at the earliest date.

Spring water supply. A supply of drinking water from springs of proved purity in the outskirts of the city was established and the water peddled from house to house at the nominal cost of one cent per gallon to the consumers. The price received for this water did not quite cover the expense of supplying it, but the outlay was trifling compared to the benefits received. As I had found in the epidemic at Ithaca, the distribution of spring water was greatly valued by the people.

To bring the water from the springs and deliver it from house to house a number of tank wagons were built. The tanks were made of galvanized iron of cylindrical shape. The capacity of these

tanks varied from 100 gallons to about 400 gallons each. They were filled through an opening at the top which was large enough to admit apparatus for cleaning. Each tank was sterilized at least twice a week with steam from a large paper mill in the central part of the city. The quality of the water was determined by daily analyses made from samples taken from the delivery wagons. The water was drawn from the tanks by means of large faucets.

At one time ten wagons were required to supply the demand for water. To facilitate the sale of the water, tickets were sold in quantity; these were exchanged by the water peddlers for the number of gallons wanted at each house. The tickets were used but once. The wagons followed fixed routes laid out on maps. Most of the city was covered in this way three times a week.

Examination of wells. Lists were made of the wells situated on private premises and on business property and arrangements were made to examine these waters. This examination consisted of, first, an inspection to determine the kind and depth of the well, its location with reference to houses, stables, and privies; the nature of the soil, and other points which would aid in interpreting the data obtained from an analysis of the water. At a later date a representative of the Board of Health visited the well and collected a sample of the water in a sterilized bottle. This sample was generally analyzed within four hours. It was examined for chlorine, hardness, number of bacteria, and the presence of coli by the presumptive test. An opinion was drawn from the results of the analysis and the record of the inspection and this opinion was then communicated to the owner of the well by postal card. Some wells were examined several times. Most wells were of unsatisfactory quality. It was necessary in a few cases to condemn and order wells closed. This was always done after a full discussion of the circumstances before a formal meeting of the Board of Health, the well being provisionally closed from the time when its condition was first determined.

Hospital arrangements. Owing to the unusual number of patients requiring to be accommodated, and the limited amount of space available for them, the two regular city hospitals were, at the height of the epidemic, greatly overcrowded. The City Hospital with forty regular beds had sixty patients. A hospital

operated by an order of Sisters of Charity, with thirty-five beds under normal conditions, was caring for fifty patients. The insanitary conditions which generally obtain in overcrowded fever hospitals were unmistakably exhibited in both of these institutions. A succession of cases of a peculiarly malignant form of erysipelas, generally accompanying typhoid, occurred in the City Hospital and in the Sisters' Hospital. Neither hospital had proper means of isolating cases of contagious disease. It therefore became necessary for the Board of Health to make arrangements for the accommodation of erysipelas and typhoid cases elsewhere. This work was done with the utmost dispatch.

Through the cordial coöperation of the Department of Charities, the headquarters of the Department on Massey Avenue were vacated and quickly made available for the erysipelas patients.

In preparing this house for its new use, every movable article was first taken out. The floors were then cleaned and painted,

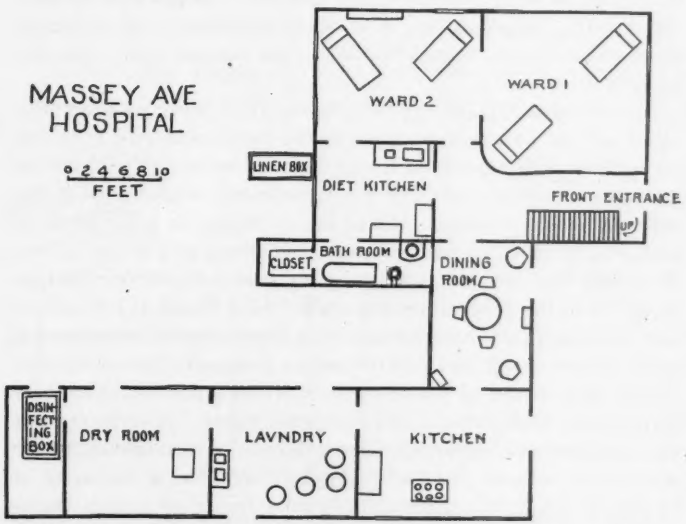


Fig. 9. Temporary Hospital on Massey Avenue opened for the Care of Erysipelas Patients, chiefly sent from the Overcrowded Permanent Hospitals of the City.

the plumbing overhauled, a disinfecting chamber large enough to contain a double mattress was constructed, a laundry was fitted out, and the house was furnished with high beds and all other appurtenances of a first-class temporary hospital. (See Fig. 9.)

In drafting the hospital regulations for this house, three general principles were kept prominently in mind: First, every part of the building was to be kept in a state of surgical cleanness. Second, no excretions, bedding, food, clothing, or other possible source or vehicle of infection was to leave the building, or the ward, if that was practicable, without disinfection. Third, every window and door was to be kept open as much as possible, and the patients, protected by screens, were to be given as much fresh air as they and their attending physicians would permit.

The results were entirely satisfactory. The disease did not spread to any of the attendants or nurses as had been the case before this temporary hospital was opened. Eleven severe cases of erysipelas were treated in this hospital. Seven were complicated with typhoid fever. The majority were in an advanced stage of the disease when admitted. One patient died. The rest recovered.

In order properly to care for the typhoid fever patients who could neither be accommodated at the permanent city hospitals nor isolated satisfactorily at their homes, a special typhoid hospital was opened. Much difficulty was experienced in finding a suitable building for this purpose. It was finally decided to use a new high school building which had just been completed at a cost of about $100 000, but not yet equipped with school furniture. Serious objection to this proposition was made by the Board of Education, but the health authorities decided that its conversion into a hospital was a necessary step and took temporary possession of the property.

The class rooms on the main floor of the school building were divided into male, female, and children's wards. A surgical ward was equipped and kept ready for emergency in case operations for perforation became necessary. Each patient had a minimum of 64 square feet of floor space and 770 cubic feet of air space. Separate rooms were reserved for patients who were very sick. Diet kitchens with gas stoves and instantaneous water heaters were established in the main hallways. Accommodations for the nurses

were provided on the second floor. A kitchen, a dining room, and a laundry were arranged in the cellar; later, the dining room and kitchen for the nurses and attendants were moved to the top floor. (See Fig. 10.)

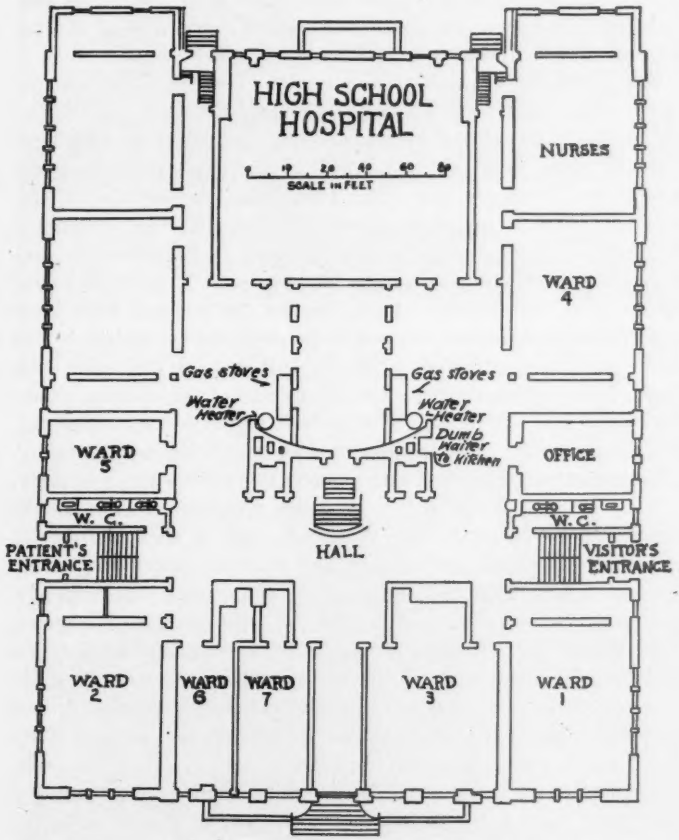


FIG. 10. The School Building which was taken by the Board of Health and turned into an Emergency Hospital for Typhoid Patients. About one hundred patients were treated. No case of typhoid occurred among the nurses, doctors, or attendants.

Rules and regulations for the management of this hospital were drafted on similar lines to those adopted for the erysipelas hospital, but they were less severe. Abundance of air in all parts of the building, thorough cleanliness in the wards, halls, closets, and nurses' dormitories, and prompt disinfection of the excretions and articles possibly contaminated with the excretions, and skillful nursing were the principles most insisted upon.

The disinfectants used were fresh milk of lime for the stools and urine, and 1 to 1 000 bichloride of mercury solution for cloths, hands, and floors. Sheets, pillow cases, and the garments of the patients, when removed, were placed in cloth bags at the bedsides and taken at once to the cellar where they were disinfected and washed. Sputum and cloths soiled with excreta, urine, or sputum were put into paper bags at the bedsides and removed in iron ash cans to a furnace in the building and burned. The cups, dishes, spoons, and other articles used in feeding the patients were kept separate for each case and regularly sterilized by boiling. The floors of all the wards were mopped with 1 to 1 000 bichloride each day. No sweeping was permitted in any part of the building. Care was taken to avoid the production of dust, by the use of damp cloths. No receptacles for milk or water were allowed to leave the building. The hospital was furnished with a fresh supply of spring water daily.

Dr. Philip C. Washburn, a graduate physician, was placed in charge of the hospital. Dr. Washburn slept in the building and was thus able to render prompt and valuable emergency aid on several occasions at the bedsides of the patients. Fortunately, no surgical operations were required. Besides Dr. Washburn, Drs. Spencer and Bibbins, prominent members of the medical profession in Watertown, kindly volunteered to serve as official medical consultants in case of need. The presence and advice of these gentlemen in connection with the medical care and nursing of the patients proved to be of great value.

None but picked graduate nurses was employed at either of the two hospitals conducted by the Board of Health. With a single exception they proved themselves capable, conscientious, and unfailing in the performance of their duties. The total number of nurses employed was 22, of which 17 were connected with the High School hospital and 5 with the erysipelas hospital.

FIG. 1. Massey Avenue Temporary Hospital, used for Erysipelas Patients. Strict isolation and disinfection were practiced. No one contracted erysipelas from these patients after they were brought here.

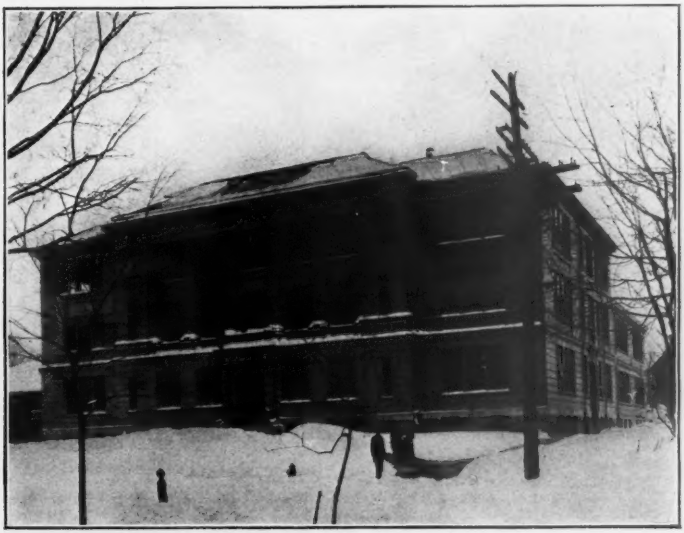


FIG. 2. New High School on Sterling Avenue, used as an Emergency Hospital for Typhoid Patients. About one hundred patients were treated here, mostly on the first floor.

The number of typhoid patients treated at the High School hospital was 97. There was but one death. None of the employees contracted the fever.

The expense of equipping and maintaining the hospitals was borne by the city. Each patient or his friends was expected to pay what he could afford for the nursing and care which the city provided, reckoned on a basis of $4.00 per week. Medical attendance was extra, and, except in indigent cases or emergencies, was provided by the patient or his family. Any physician in good standing was permitted to send and attend cases of typhoid at this hospital. For the removal of the patients from their homes, a specially constructed ambulance was provided without charge.

It is impossible to refrain from referring to the valuable help given by the ladies of Watertown in fitting out these two hospitals. Much help in the way of purchasing supplies, sewing, and aid of a kind that men cannot give was contributed by them with a promptness and generosity which added much to the success of the undertaking.

The bacteriological laboratory. A bacteriological laboratory was established for the analysis of water, milk, blood, urine, and other work in connection with the suppression of the epidemic. All the apparatus was of the best quality and purchased new. Dr. Herman Requi, of the University of Chicago, was placed in charge of the laboratory and was given enough help to enable him to turn out prompt and accurate reports. The work of this laboratory was done at the expense of the city and without charge to any individual.

Widal examinations to assist in the diagnosis of suspected cases of typhoid fever were given first place in the routine of the laboratory. No limit was placed upon the number of examinations which would be made for any physician or patient. If a specimen of blood reacted negatively, the physician who sent it was advised to furnish another specimen from the patient at a later date.

As I had found elsewhere, the only practicable way to obtain many specimens of blood for the Widal test was in the form of drops of blood dried on cards. Several races of typhoid and typhoid-like bacilli were kept in culture and were used when the

ordinary typhoid bacillus failed to agglutinate in proper dilution with the serum dissolved from the dried blood. Up to April 21, there had been examined 251 samples of water, 98 specimens of blood, and 95 specimens of urine.

Board of Health disinfectants. Disinfection was practiced in several ways. At the outset an effort was made to introduce uniform methods of disinfection in as many of the fever houses as possible. Because of the unreliability of the proprietary disinfectants sold in the shops, the Board of Health established a central disinfectant bureau and from this point distributed, without cost to the consumers, disinfectants throughout the city. Several wagons were employed to carry freshly slaked lime and concentrated bichloride of mercury to each house in which a case of typhoid fever was known to exist. Every fever house was thus visited twice a week, sometimes oftener. The disinfectants which were sent out on the wagons were known as "white fluid" and "blue fluid," and were of such concentration that, upon adding to either four times its volume of water, it would be of proper strength for use. The milk of lime, or white fluid, when ready for use, was composed of one part of freshly slaked lime to eight parts of water. The bichloride of mercury solution employed consisted of one part of bichloride of mercury to one thousand parts of water; this was made acid with hydrochloric acid and colored blue with common washing bluing. Directions for using both of these disinfectants were printed in large type on stout sheets of cardboard and left at each house where the disinfectants were employed.

Fumigation with formaldehyde was performed by the Board of Health at each house after a case of fever unless there was good reason to believe that this precaution was unnecessary. The method of generating the formaldehyde first used was that regularly employed by the Watertown Board of Health. It consisted in the use of a lamp with paraform pastils from which the gas was expelled. Later, because of the large number of houses which needed to be fumigated, a more rapid method was adopted. After the room had been closed as air tight as possible, and rugs, draperies, bedding, and other similar articles had been hung on chairs or suspended in the middle of the room, a large sheet was hung up. From a small watering pot there was then poured upon this sheet

a solution of formalin of 40 per cent. strength, in the proportion of at least 3 pints for every 1 000 cubic feet of air space, not allowing for the space taken up by the furniture and other articles in the room. After twenty-four hours all the windows were opened and the place thoroughly ventilated for at least two days. A careful scrubbing of the woodwork with soap and water and a brushing of the upholstery and drapery followed.

As a test of the efficiency of the fumigation, threads freshly impregnated with typhoid bacilli from twenty-four hour broth cultures were exposed in the room during the vaporization of the formaldehyde. After the disinfection the threads were immediately placed in sterile broth in the laboratory. If there was no growth this was taken to mean that the fumigation had probably been sufficient to destroy such bacilli of typhoid as may have been in the room as a result of its occupancy by the typhoid fever patient.

Other sanitary measures. The steps thus far described were the principal ones taken to prevent the spread of the fever, but they were not all. In many other ways the Board of Health endeavored to check the epidemic. The physicians were urged to report their cases accurately and promptly, and if they did not all comply, it was less the fault of the local board than to the neglect of this custom which commonly prevails in American cities.

Complaints of alleged nuisances were diligently investigated, and an effort made to have all houses and back yards put in order. The regulations of the Board of Health were revised, collated, and digested. The questions of garbage collection and disposition were studied, and the existing and other possible means of disposing of household wastes were inquired into.

Learning that smallpox existed in the vicinity of Watertown, an isolation hospital on the outskirts of the city was kept especially for the reception of patients suffering from this disease. Fortunately, it was not needed, but in anticipation of an emergency it was overhauled, cleaned, and put in readiness.

The sanitary awakening which resulted from the epidemic was the more remarkable from the fact that Watertown had been, in spite of its long and sinister typhoid history, a more than ordinarily well-regulated city.

Coöperation received in the sanitary campaign. As soon as the Board of Health began active work for the control of the epidemic, gratifying evidences of coöperation became apparent in many directions. The hospital authorities asked the board for help in difficulties connected with the overcrowded conditions of the hospitals, and offered such aid as they could give in other directions. Requests came from the press and the pulpit for interviews and addresses on sanitary topics. Organizations, corporations, and private citizens tendered their services and desired to be instructed in ways in which they might be of assistance in the general sanitary campaign. It was thus comparatively easy to carry to the people a knowledge of those principles of sanitation which were peculiarly applicable to the situation.

In endeavoring to give the instruction desired, particular emphasis was placed upon the value of simple but thorough methods of cleanliness and order, indoors and out. It was early pointed out that it was desirable that the storm doors and windows which had closed many houses from the outer air during the whole of the long, severe winter be removed as soon as possible. As the spring advanced, the people were advised to begin their annual housecleaning early and make the work more than ordinarily thorough. Improved methods of collecting and disposing of the wastes so produced were undertaken by the city.

On the educational side, conferences were held with the physicians who practiced in Watertown and vicinity, and addresses were made before the local medical societies. The subjects dealt with on these occasions included the discussion of the nature and origin of typhoid fever; the paths and channels by which the infectious germs are communicated; the value of the Widal test; the importance of watching the urine for typhoid bacilli; the need and methods of eliminating typhoid germs from the urine when found; the necessity for sending to the Board of Health prompt and accurate reports of cases of typhoid fever; disinfection; the purification of water and sewage and the disposal of garbage and other municipal wastes.

From the first the physicians coöperated with the health board in a most encouraging and helpful manner. It is largely due to the help thus received that the work of the Board of Health was

successful and the number of cases of comrade or house infection was kept small.

The Chamber of Commerce and various other less prominent bodies entered cordially into the work. The Chamber, in fact, had been largely instrumental in causing the sanitary campaign to be undertaken.

The officers of the St. Regis Paper Company of Deferiets placed themselves under the direction of the Board of Health and carried out in the village surrounding their plant a careful plan to exclude infectious matter from continuing to enter their sewers which flowed into the Black River.

Charles F. Bingham, mayor; John B. Rogers, president of the Board of Health; Dr. E. S. Willard, health officer; and Mr. Theodore Ely Knowlton, representing the Chamber of Commerce, were indefatigable in giving personal attention to the work. To all the employees of the board credit is due for services of an unusually arduous nature; it is impossible to name all, but a special word of appreciation belongs to E. J. DeLong, principal office assistant.

DISCUSSION.

THE PRESIDENT. The paper is now before the Association for discussion. Perhaps Dr. Sedgwick will speak to us first.

PROF. WILLIAM T. SEDGWICK.* Mr. President and fellow members: It has been said repeatedly that the human race does not seem able to learn by recorded experience. It has got to suffer and learn by its own repeated and individual personal experience. And it seems to me that this epidemic wonderfully illustrates that point. The date of the epidemic was comparatively recent; and ever since 1885, when the great typhoid epidemic took place at Plymouth, Pa., it had been as clear as daylight to anybody that it was not wise to drink polluted water. Nevertheless, here was one of the proud cities of New York which continued to do that in full face of all the danger that must necessarily be connected with drinking it. It was apparently necessary for that city to sacrifice a lot of lives in order to be brought to the point of cleaning up its water supply.

There is nothing peculiar to Americans in this. It was the same

* Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

in Hamburg in 1892. Hamburg had long been using a highly polluted water; typhoid was very high, and other diseases were abnormally high; but it took an epidemic of Asiatic cholera of international fame to cause the introduction of a purified water supply into that city. It seems to be a characteristic of civilized man everywhere that he is not able to learn by recorded experience.

We are having the same sort of experience with our schoolhouses to-day. It took the sacrifice of one hundred and sixty children in the central part of the country to teach school boards everywhere that it was important to look out for exits from schoolhouses and to have fire drills rightly conducted. I suppose to-day the lives of all school children are infinitely safer with respect to fire than they were a month ago, because of the sacrifice of these victims.

The moral of all these things is that we need to keep high standards in water supplies, and in every branch of civilized life; that we need better administration, we need higher moral tone among those charged with public responsibilities. And I believe that this Association has long stood for that higher tone. I believe there is not a member of it who, if supplying water under the conditions described by Dr. Soper, would not spend wakeful nights, and possibly even resign his position, rather than continue to supply water to his people in the face of dangers as grave as those which confronted Watertown. If there be any such man, it is high time he resigned his place. We have got to keep high standards in this matter, and I think we are all indebted to Dr. Soper for making that fact so clear to us. There is nothing new in the water pollution part of his story. We all know that it is the same thing which we have heard over and over and apparently have got to hear for many years to come, before we in America, and others in other parts of the world, learn that it is not safe even for one day to continue the consumption of a water exposed to serious pollution without first purifying that water and protecting it in some way.

Dr. Soper's great work has been in showing that typhoid fever ought to be treated as a contagious disease. If I am not mistaken, his work has been more thorough in this respect than that of any member of this Association, and probably of any other man in this country. And it was also early work. In his very effective

measures applied at Ithaca, and repeated here at Watertown, he has shown from the start a logical mind in that he has been led to carry through to the uttermost the obvious measures which were required to drive typhoid fever out of a community; and I know of no one who has been so painstaking and so thorough in this respect.

It happens that his work is just now extremely timely because, owing to the emphasis at present laid upon typhoid carriers, and for various other reasons, mainly bacteriological, which I need not stop to detail, the world is waking up to the fact that typhoid fever ought to be treated as a contagious disease. And here again we have to say that we have been very slow, all of us, and perhaps reprehensible even, in having put off so long the recognition of this fact, and the pushing of it to its logical conclusions, for the moment we examine the history of typhoid fever we find that from the very beginning it was recognized by many who investigated it to be a highly contagious disease.

We water-works people, however, are to be pardoned in large measure in this direction, because physicians have for a long time been in the habit of saying, when called to a family having typhoid, and when questioned as to the danger for the other members of the family, " You need have no fear; typhoid is not a contagious disease, it is only infectious." These physicians were in the wrong, as we know to-day, and as we might have known for a good while if we had only given heed to the best of physicians. It is a curious and interesting fact that when typhoid was first worked out in 1829, and separated from jail fever and ship fever and the other forms of typhus fever with which it was previously confounded, — I say it is an interesting and it has been an unfortunate fact, that a large part of the differentiation between the two was made to consist in the fact, or the alleged fact, that typhus fever, the old-fashioned jail and ship fever, is contagious, while typhoid is not. Now in a very rough and rude way that is true. Typhoid is not as contagious as typhus is, and it is not as contagious as smallpox or scarlet fever or as a good many other of the so-called and admittedly contagious diseases. But owing to the emphasis laid upon this differential point between the two diseases, physicians themselves took the ground that typhoid was comparatively

non-contagious and typhus comparatively contagious; and, as time went on, the idea was spread abroad, very naturally, that typhoid is not contagious, and physicians generally have thought so and have said so over and over again. Whereas, the truth is this: Typhoid is not as contagious as many other diseases, but it is truly contagious, nevertheless. It is a contagious disease, and it is a matter of satisfaction to me, and must be to every one who has treated it as such for a number of years, that some of us, at any rate, have said so, and were in print years ago as having insisted on that fact.

Now Dr. Soper, fortunately free from traditional prejudice in this matter, and following up the logical conclusions drawn from bacteriology, no doubt, has from the outset acted as if typhoid is practically a contagious disease, and as if the way to fight it is to treat it as such; and in his work at Watertown and at Ithaca and elsewhere he has honored the water-works profession, and the laity, of which he is a member, by having acted up to his convictions. Therein lies his distinction, because some of the rest of us who have known the facts, perhaps just about as well, have not so acted, or, at least, have not acted to the same extent. And I am glad he showed you in somewhat elaborate detail his hospitals of various sorts, and that he has told in his paper of the pains taken to disinfect and to get rid of infection. This is most honorable to him as an engineer and as a member of the water-works profession. In doing this he has actually led the way for boards of health to-day. It required a man like him to teach the Watertown board of health how to handle an epidemic of this sort. And the same thing was true in Ithaca, I believe, and elsewhere.

We have here the rounded whole. We have the clear proof of water infection; we have then the scientific and logical following through to the uttermost of the consequences of that conclusion, with insistence upon such a treatment of the epidemic as is required by our modern knowledge. The bacteriological progress which has been made, and especially certain discussions in Germany, have shown that it is easy to find the causal germ in early stages of the disease. And boards of health are beginning to wake up to the fact that typhoid has got to be treated in every respect as a contagious disease. Though admitting that it is not as con-

tagious as some other diseases, it is still to all intents and purposes contagious.

From another point of view, work of this kind tends to shed light upon that residual amount of typhoid fever which remains in a community after the water supply is perfected. In the case of Washington, for example, I have no doubt that it will eventually turn out, as the editorials in *Engineering News* have encouraged us to believe, that a large part of the typhoid fever still lingering there, after the water has been thoroughly purified, will prove to be spread by ordinary, old-fashioned contagion. All of which is important for us as water-works men. If typhoid fever in Washington remains high after a good filter is introduced, discredit falls perforce upon the filter. We need to know about this residual typhoid; we need to know what causes it, and if by proper disinfection and proper treatment, such as Dr. Soper has so very well outlined, we are able to reduce typhoid fever in any community to zero, or very nearly to zero, as I believe we shall be able to do when once these processes of disinfection have been installed, then the work will be of value not only as a lesson to boards of health, but as serving to protect those of us who are interested primarily in pure water. In more than one instance it has turned out that the purification of the water supply has not adequately diminished typhoid fever in the city affected, and one of the reasons is, apparently, a lack of this very thoroughness, this masterly grasp of details, which Dr. Soper has shown can be made effective, and which he was one of the first to display. It is for this reason, it seems to me, that the paper is of special value and of much timeliness, and I, for one, feel greatly indebted to Dr. Soper for his careful presentation of it here and now.

PROF. C.-E. A. WINSLOW.* Dr. Soper's account of the Watertown epidemic has interested me greatly and I am sure that others must feel, as I do, gratified that he should have reported his investigations through the medium of the New England Water Works Association. We have all of us grown to look with the pleasantest anticipations to Dr. Soper's visits to Boston, for he has always something to tell us which we want to hear.

* Assistant Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

The Watertown case as presented to-day appeals to me particularly as an indication of the new attitude which sanitarians are rightly adopting toward typhoid fever. Here is primarily a water-borne epidemic, and yet most of Dr. Soper's paper has dealt with preventive measures which have nothing to do with water supply. This means that the views which Professor Sedgwick and I had the honor to present to this Association in 1906 * have gained general acceptance to-day and that sanitarians now realize that water is only one factor in the causation of typhoid fever. In many communities this disease has no relation whatever to water supply, and even where polluted water is the prime cause, its influence is multiplied and extended by a host of other channels of infection.

The water-borne typhoid is easy to deal with. Cities which continue to drink sewage do so with their eyes open or in willful and deliberate ignorance. The factors which produce prosodemic typhoid, on the other hand, typhoid which spreads from person to person by various vehicles, are much more obscure and less easy to control. It is fortunate that in this particular case the authorities of Watertown atoned for their early neglect by prompt remedial measures after the epidemic of 1904. It is significant that in so doing they did not content themselves with retaining the ablest engineering talent in connection with purer water, but called in also our guest of the afternoon, who has made a national reputation as a specialist in the eradication of residual typhoid.

It is this prosodemic or residual typhoid which now constitutes the great bulk of the disease in the United States. Even in Watertown since the filtration of the water supply it still causes excessive death-rates, according to Dr. Soper's figures. Rates of 50 per 100 000 in 1906, and of 37 per 100 000 in 1907, demand some explanation. The truth is, we are only at the beginning of our knowledge of typhoid fever, in spite of the fact that probably no disease except tuberculosis has received so much attention. There is one factor in particular to which almost no attention has hitherto been paid, but which I am inclined to think is soon to receive a new share of attention, and this is the varying predisposition of the

* JOURNAL, March, 1906, Vol. XX, p. 51.

host. I should like to occupy a moment in calling your attention to this neglected point.

It is well known that typhoid fever, where not due mainly to polluted water, follows the curve of temperature with remarkable closeness. Recent investigations at Washington and at Youngstown, Ohio, have shown this with great clearness, and the phenomenon appears to be a universal one all over the world. Comparing different geographical areas, too, it is well known that typhoid on the whole is most prevalent in warm climates, but I did not myself realize how close this relation was until I analyzed, a day or so ago, the census returns for the Atlantic states according to their geographical position. As indicated in the table below, the typhoid rates for the white population average in the North Atlantic states about 30 per 100 000, and, with the exception of Pennsylvania, lie between 17 and 31; Pennsylvania's high rate of 44 is, of course, due to the large quantity of polluted water which was consumed in that state in 1900. The second group of states from Ohio to North Carolina shows an average death-rate of 54, and the individual rates range from 42 in Maryland to 76 in Kentucky. Finally the southeasterly and Gulf states show an average death-rate of 81, with individual variations from 57 in Florida to 93

TABLE V.

TYPHOID IN THE ATLANTIC STATES IN RELATION TO LATITUDE.

Death-rate per 100 000. Among whites only.

(United States Census for 1900.)

NORTHERN GROUP.		MIDDLE GROUP.		SOUTHERN GROUP.	
State.	Typhoid Rate.	State.	Typhoid Rate.	State.	Typhoid Rate.
Maine,	29	Ohio,	43	Tennessee,	84
New Hampshire,	17	Maryland,	42	South Carolina,	72
Vermont,	31	Delaware,	53	Georgia,	80
Massachusetts,	22	Dist. of Columbia,	69	Florida,	57
Rhode Island,	24	West Virginia,	62	Mississippi,	87
Connecticut,	27	Virginia,	48	Louisiana,	71
New York,	25	Kentucky,	76	Alabama,	93
Pennsylvania,	44	North Carolina,	70		
New Jersey,	21				
Group,	30	Group,	54	Group,	81

in Alabama. Of course such gross death-rates as these are affected by many other factors than temperature. The water supplies in individual cases are worse than in others, but on the whole I think there can be no doubt of the general lesson to be drawn from this table. Pennsylvania, with its heavily polluted water supplies, is found, it will be noticed, in the northern group, and the District of Columbia in the middle group. There seems no escape from the conclusion that there is a striking direct relation between temperature and the prevalence of typhoid fever.

In reviewing the question of seasonal prevalence in 1902, Professor Sedgwick and I were inclined to explain the autumn maximum as follows:

"The bacteriology and the etiology of typhoid fever both indicate that its causal agents cannot be abundant in the environment during the colder season of the year. The germs of the disease are carried over the winter in the bodies of a few patients and perhaps in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharges of these winter cases will depend, other things being equal, upon the length of time for which the bacteria cast in these discharges into the environment remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry to a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in nature of germs which proceed from previous victims of the disease."

My own confidence in the theory that the seasonal prevalence of typhoid is due to the effect of temperature upon the germ alone was somewhat shaken by a study of the admirable report upon the origin and prevalence of typhoid fever in the District of Columbia by Dr. Rosenau and his associates, published by the Hygienic Laboratory of the Public Health and Marine-Hospital Service. It appeared that in 1906 the typhoid curve did indeed follow in general the relation of the temperature, but that its greatest rise was not gradual but sharp, coinciding with the period of extreme hot

weather in the middle of July. The conception of the seasonal curve as due to the action of temperature upon the germ in the environment presupposes a very gradual change, and it is difficult to see how a sudden period of hot weather could produce a sudden reaction. If, on the other hand, the temperature affects typhoid incidence in part by a direct lowering of the vital resistance of the host, such a phenomenon might be expected. I have recently come upon striking confirmatory evidence of this latter theory. An extremely suggestive monograph on enteric fever in India has recently been published by Major Ernest Roberts of the Indian Medical Service (Calcutta: Thacker, Spink & Co., 1906). In this most important contribution to the etiology of typhoid fever, Major Roberts emphasizes his own belief in the importance of the vital resistance factor in the spread of typhoid. As he puts it: "Both host and parasite are definitely subject to the influence of the environment as it produces any seasonal changes; that both live and thrive by adaptation only; and that the problem of acclimatization or colonization is the same for both, — a contest for supremacy by immigrant races." The most striking evidence which Major Roberts adduces for the support of this view is included in the following table which shows that whereas the typhoid among the European troops in India follows the general rule and is concentrated in warm weather, that in the native troops follows an exactly reverse course. This seems difficult to explain on any theory of germ distribution. If germs are most abundant in warm weather they should affect both English and natives at that time. If, on the other hand, the relation of temperature to vital resistance of the host is a prime factor, we might expect just such a relation as is indicated in the table. Certainly English troops must be much more affected by the hot weather of India than the natives, and it is possible that the natives may in their turn be unfavorably affected by the colder season in many parts of the peninsula.

TABLE VI.

PERCENTAGE OF TOTAL MORTALITY.

	HOT SEASON. (May to Oct.) Per Cent.	COLD SEASON. (Nov. to April.) Per Cent.
European troops	62	38
Native troops	37	63

It seems to me clear that we have in the etiology of typhoid to reckon with three factors: First, the number of active germs present in the environment; second, the vehicles, water supply, milk supply, filth, etc., available for transmission of germs to the patient; and third, the vital resistance of the patient himself. It is perfectly possible according to this theory for an individual in good health to receive typhoid germs without succumbing to the disease, just as we know to be the case in tuberculosis and other disorders of the respiratory tract. A period of extreme hot weather, on the other hand, either by direct effect on the organism or through favorable indirect influence on fermentations in the digestive tract, upsets the defensive mechanism of the alimentary canal and we get a sudden sharp increase of typhoid fever. This, without in any way excluding the direct effect of temperature upon the germ in the environment, helps to explain the prevalence of fall fever and the increase of typhoid in warm climates. It helps also perhaps to explain the general excess of typhoid fever in this country as compared with that which obtains in northern Europe. It still remains true that a very large amount of the typhoid which exists in this country constitutes a national reproach. The prospects for the future, however, are bright and we may look to see residual typhoid wiped out in the future as water-borne typhoid is rapidly being eliminated to-day. When this is done it will be by just such forceful and thorough and painstaking campaigns as that which Dr. Soper has carried out at Ithaca and Watertown.

Mr. George C. Whipple * (*by letter*). The writer has been interested in reading Dr. Soper's paper, partly because of his general interest in the subject of epidemics and their relation to public water supplies, and partly because he is familiar with the present conditions in Watertown. From the facts which have been so ably presented many important lessons may be drawn. Some of these have been already mentioned by Professor Sedgwick and others. The more that epidemics of typhoid fever are studied, the more sanitarians are coming to appreciate the fact that this disease is contagious as well as infectious. In every large epidemic many of the cases, especially the late cases, are

* Consulting Engineer, New York City.

caused not by the original infection, but, as we say, by "secondary infection," that is, by direct contagion from early cases. This was strikingly shown in the typhoid fever epidemic that occurred in Gelsenkirchen, Germany, a few years ago. This epidemic was caused by an infection of the public water supply, but a careful study of the situation showed that a large proportion of the cases that developed near the end of the epidemic were due to contagion. This is interestingly shown by the following diagram, Fig. 11.

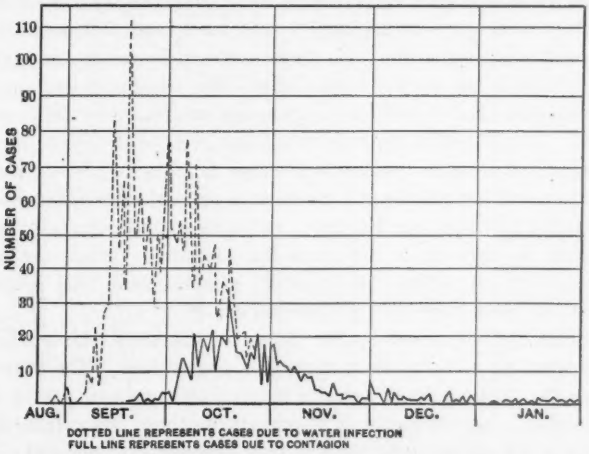


FIG. 11. DIAGRAM SHOWING THE PROGRESS OF THE TYPHOID FEVER EPIDEMIC IN GELSENKIRCHEN, GERMANY.

It was the prevention of these cases of secondary origin to which the work of Dr. Soper in Watertown was chiefly directed. How far he was successful in accomplishing the result cannot be definitely shown from the data presented, but there is no reason to doubt that many lives were saved by the sanitary reforms that were inaugurated under his direction.

It was unfortunate for the city that more stringent measures to quell the disease were not taken earlier in the history of the epidemic. The long duration of the epidemic shows that the water supply must have been in a continually infected condition for many weeks, as the city had but a small storage reservoir and

the water was pumped for most part directly into the mains. Apparently the measures taken to avoid the secondary cases were more elaborate and probably more effective than those taken to do away with the infection of the river water. The early history of the epidemic is an illustration of the procrastination which so frequently occurs even in the most intelligent communities. Apparently the epidemic had been running for nearly a month before any active measures were taken to get control of the situation. It would seem as if the occurrence of more than twenty cases during the first three days of January would have been followed by an immediate investigation. In these matters, however, the city of Watertown is not very different from other communities, nor can it be claimed that the officials were more lax than they are in most cities. In all health departments there is a tendency to regard the reported cases of infectious diseases as facts for history rather than as facts for prophecy. Such data are valuable for purposes of record, but they are far more valuable as indications of what is likely to happen in the immediate future. Unless the data reported by physicians are carefully studied from this point of view they lose a large part of their value.

Of the methods used by Dr. Soper in checking the epidemic little need be said, as they speak for themselves. The ways in which the typhoid fever germ is transmitted are now pretty well understood, and the methods of preventing these germs from finding their way from some patient to a new victim are pretty well known by water-works men, and have been the subject of repeated discussion in this Association. The writer is inclined to think that up to the present time too little attention, perhaps, has been given to the barriers that should be established to prevent the scattering of the germs from the patient; that is, to disinfection. The stamping out of this disease can only be done by coöperative work, in which physicians, nurses, engineers, and many others play a prominent part. In order to illustrate this fact the writer has made use of the simple diagram which is here presented, Fig. 12.

Mention has been made of the fact that a filtration plant was put in operation in Watertown in 1904.

Since the introduction of this filtration plant the typhoid fever

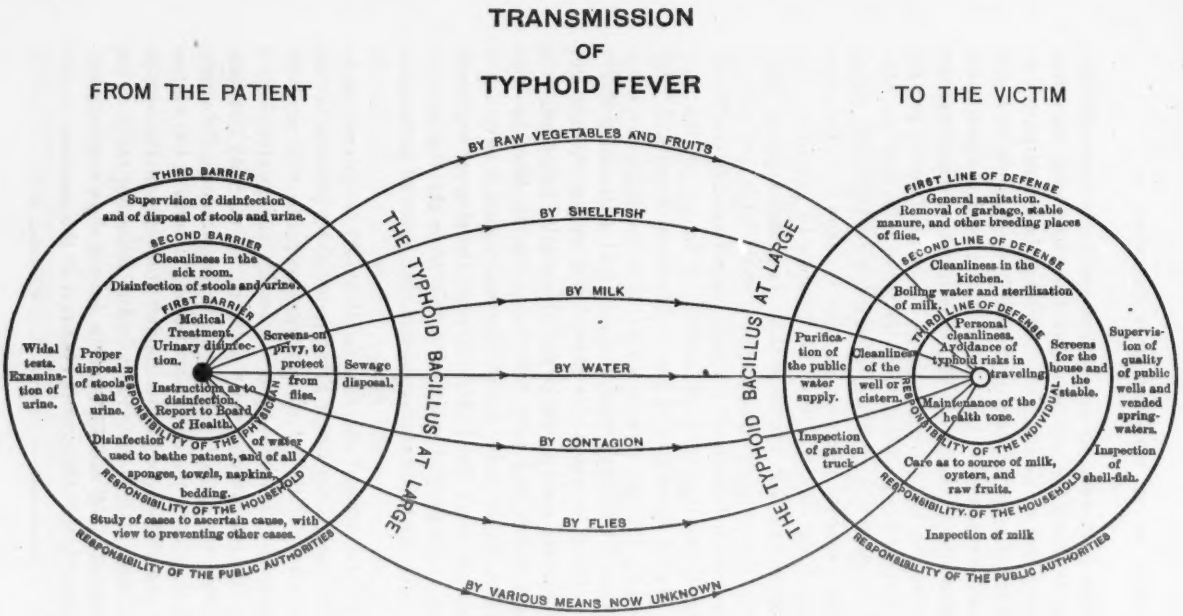

TRANSMISSION
OF
TYPHOID FEVER
FROM THE PATIENT
TO THE VICTIM
THIRD BARRIER
Supervision of disinfection and of disposal of stools and urine.
SECOND BARRIER
Cleanliness in the sick room.
Disinfection of stools and urine.
FIRST BARRIER
Medical Treatment.
Urinary disinfection.
Instructions as to disinfection.
Report to Board of Health.
Disinfection of water used to bathe patient, and of all sponges, towels, napkins, bedding.
Study of cases to ascertain cause, with view to preventing other cases.
Widal tests. Examination of urine.
Proper disposal of stools and urine.
Screens on privy, to protect from flies.
Sewage disposal.
RESPONSIBILITY OF THE PHYSICIAN
RESPONSIBILITY OF THE HOUSEHOLD
RESPONSIBILITY OF THE PUBLIC AUTHORITIES
THE TYPHOID BACILLUS AT LARGE
BY RAW VEGETABLES AND FRUITS
BY SHELLFISH
BY MILK
BY WATER
BY CONTAGION
BY FLIES
BY VARIOUS MEANS NOW UNKNOWN
THE TYPHOID BACILLUS AT LARGE
FIRST LINE OF DEFENSE
General sanitation.
Removal of garbage, stable manure, and other breeding places of flies.
SECOND LINE OF DEFENSE
Cleanliness in the kitchen.
Boiling water and sterilisation of milk.
THIRD LINE OF DEFENSE
Personal cleanliness.
Avoidance of typhoid risks in traveling.
Maintenance of the health tone.
Purification of the public water supply.
Cleanliness of the well or cistern.
Inspection of garden truck.
Screens for the house and the stable.
Supervision of quality of public wells and vended spring-waters.
Inspection of shell-fish.
Care as to source of milk, oysters, and raw fruits.
Inspection of milk
RESPONSIBILITY OF THE INDIVIDUAL
RESPONSIBILITY OF THE HOUSEHOLD
RESPONSIBILITY OF THE PUBLIC AUTHORITIES
AND
MEANS OF PROTECTION

FIG. 12. (FROM "TYPHOID FEVER: ITS CAUSATION, TRANSMISSION, AND PREVENTION," BY GEORGE C. WHIPPLE.)

death-rate has been very materially decreased. It has not fallen quite as low, however, as it has in some other cities after the water has been subjected to purification. This has been due partly to the occurrence of cases apparently caused by contagion, as many of them were located near the outskirts of the city where there was no water supply; partly to the importation of cases that developed elsewhere; and partly, perhaps, to the existence of private water supplies for fire purposes in a number of mills that are connected with the city mains and provided with the usual check valves. The water for these fire supplies is taken from the river in the heart of the city and is obviously open to pollution. No direct evidence has been obtained that these mill supplies have been actually the cause of any cases of typhoid fever, but in view of the fact that such connections have caused trouble elsewhere, it cannot be denied that they are a source of danger, or that they may have played some part in the continuance of typhoid fever in Watertown. Certain it is, however, that the filter plant has shown a hygienic efficiency that compares well with similar filters elsewhere. The filter plant is in charge of a trained chemist and bacteriologist who very regularly and frequently makes analyses of the water before and after filtration. As this filter has not been described to the members of this Association I have taken the liberty of inviting Mr. F. H. Jennings, the chemist in charge of the plant at the present time, to contribute to this discussion a statement covering the operation of this filter since its installation in 1904.

Mr. F. H. Jennings * (*by letter*). It would be interesting to compare analyses of the Black River water as supplied to Watertown in the winter of 1903–4, if they were available, with analyses made subsequent to that time, especially the bacteriological analyses. The raw water counts obtained at the city filtration plant in Watertown in the months of December, January, February, and March show only moderate numbers of bacteria in the winters of 1904–5 and 1905–6, but much higher numbers in the winters of 1906–7 and 1907–8, as shown in the following table. The counts obtained in the summer months did not show a corresponding variation, though the counts obtained in the summer months

* Superintendent of Filtration Plant, Watertown, N. Y.

of 1907 were rather higher than in the preceding summers. At the same time, the positive presumptive tests for colon in one cubic centimeter samples of the raw water were more frequent in the winters when the counts were low than when they were high, averaging for the winter of 1904–5, 94.5 per cent., and for the winters of 1906–7 and 1907–8, 41.5 per cent. of the tests made.

TABLE VII.

BACTERIA IN BLACK RIVER WATER AT WATERTOWN, N.Y.

		1904.	1905.	1906.	1907.	1908.
January	Average		7 480	2 721	64 150	23 900
	Maximum		27 700	12 600	18 900	49 200
February	Average		2 200	2 033	21 410	40 800
	Maximum		4 920	5 000	52 600	138 300
March	Average		7 800	3 950	66 470	
	Maximum		30 900	17 000	134 100	
December	Average	2 960	708	39 800	30 480	
	Maximum	16 500	5 300	59 500	71 800	

A preliminary survey of the watershed made in the spring of 1907, covering sixty miles of the river above Watertown, in an effort to locate some specific cause of these higher counts, showed that they were general on the main stream and all the principal tributaries. During the winter of 1906–7 there was comparatively little snow, but during the winter just passed the snow was deep all over the Black River country. The general temperature was about the same in the two winters, so we could find no explanation of the higher counts in climatic conditions. During both winters the river was completely frozen over.

The chemical and physical characteristics of the water also vary widely. There are a number of paper and pulp mills on the river above Watertown, both chemical and mechanical processes being used. The effect of the chemical waste is quite apparent in times of low water in the river. A change of color of twenty-five parts per million (platinum scale) in four hours is not unknown here. This may mean an increase of 30 per cent. in the color in four hours. This color change is frequently accompanied by a decrease in the alkalinity of the raw water.

Since the installation of the filtration plant there has been a marked reduction in the typhoid death-rate, as shown by Table I in the paper under discussion, and a still more marked reduction in the typhoid morbidity rate, as is shown by the following table based on figures obtained from the annual reports of the local health officer:

TABLE VIII.

Year.	Population.	Cases of Typhoid.	Cases per 100 000.	
1900.....	21 696 (census)	193	877	
1901.....	22 400 (estimate)	150	670	
1902.....	23 200 „	306	1 319	
1903.....	23 900 „	231	967	
1904.....	25 000 „	703	2 812	(Epidemic year. Filter plant in operation September 12.)
1905.....	25 447 (census)	108	424	
1906.....	27 500 (estimate)	130	473	
1907.....	30 000	103	343	

In considering the morbidity rate it should be remembered that Watertown is the center of a large district having no hospitals except those in Watertown, so that a considerable proportion of the cases reported are imported, —brought to the local hospitals for treatment and reported from there. For instance, in 1907, the only year for which I have the figures, there were 20 such cases, or 19.4 per cent. of the total cases reported. If these 20 cases be deducted the morbidity rate becomes 277 instead of 343.

I know of no local explanation of the higher mortality and morbidity rates for 1906 than for the other years since the filtration plant was established. I understand that typhoid was more prevalent than usual throughout northern New York in 1906, so it seems to have been a general condition rather than a local condition.

Previous to the installation of the filtration plant high monthly typhoid morbidity rates were rather general, occurring at no particular season; but since the installation of the plant the high morbidity rates have occurred in the fall months, when other causes than water supply are most active, as shown in Table IX.

The filtration plant in Watertown has been in operation now about three and one-half years, and it may be of interest to consider

TABLE IX.

CASES OF TYPHOID BY MONTHS.

Month.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
January	13	23	180	7	7	18	2
February	16	47	302	4	10	7	3
March	37	29	101	17	4	8	
April	30	18	31	7	6	7	
May	26	3	19	3	2	6	
June	18	9	3	0	1	9	
July	22	23	11	3	3	0	
August	28	22	3	8	15	9	
September	39	21	21	12	26	15	
October	30	14	13	20	26	15	
November	20	7	14	10	18	3	
December	27	15	5	7	12	6	

the operation a little more in detail. The figures given in the following tables show this clearly. These figures are in all cases the monthly averages obtained from the records kept at the filtration plant. Table X shows the principal water quantities for the period.

During the winter of 1904–5 the water consumption was very high owing to leakage and waste, largely the latter. A campaign against this waste resulted in a lower consumption, but as the city grows larger the consumption is going up again, so that there have been times this last winter when it was difficult to keep up the supply of filtered water.

It will be noticed that during the last three months for which figures are given above, the period of service has been longer than usual; in fact, it has been necessary to make a rule that the filters should be washed at the end of forty-eight hours whether or not there was need of it to keep up the supply of filtered water. We ordinarily wash when the water falls to a certain level in the clear water well, experience having shown that, with us, this is better than washing at a certain loss of head on the filters.

The low values for the amount of water filtered between washings in the months of June, July, August, and September, 1907, were due to difficulties in the operation of the plant ensuing from the low stage of the river.

TABLE X.

Month.	Amounts of Water Filtered in Million Gallons per Day.	Percentage of Wash and Waste Water.	Number of Filters Washed Daily.	Period of Service in Hours.	Amount of Water Filtered between Washings, in Million Gallons.
1904.					
October....	4.418	6.7	12	15.40	0.371
November..	4.622	3.6	8	24.58	0.575
December..	5.250	3.8	11	18.59	0.475
Average .	4.760	4.7	10	19.52	0.473
1905.					
January ...	5.458	3.2	8	21.57	0.674
February ..	6.090	4.6	15	13.62	0.409
March	4.980	4.2	12	16.45	0.417
April	4.157	3.0	6	27.91	0.643
May.....	4.322	3.8	10	18.38	0.432
June.....	4.662	4.6	11	17.63	0.457
July.....	4.541	3.9	7	20.05	0.428
August	4.296	5.3	11	16.81	0.414
September .	4.283	3.4	7	25.04	0.568
October....	3.797	3.5	7	21.26	0.546
November .	3.909	3.7	7	25.96	0.548
December..	4.234	3.3	7	26.37	0.601
Average .	4.561	3.9	9	20.92	0.512
1906.					
January ...	4.302	3.3	7	26.95	0.617
February ..	4.326	3.2	7	26.17	0.617
March	4.274	3.1	7	24.49	0.602
April	3.850	2.8	5	29.79	0.749
May.....	3.282	3.2	7	24.43	0.653
June	4.177	4.3	9	22.56	0.595
July.....	4.184	4.5	10	20.04	0.501
August	4.096	4.5	10	20.91	0.495
September .	4.058	4.3	9	23.77	0.526
October....	3.793	3.8	7	24.59	0.563
November .	3.485	2.5	5	39.98	0.726
December..	4.108	2.9	6	29.46	0.773
Average .	3.995	3.5	7	29.10	0.618
1907.					
January ...	4.142	2.3	5	33.66	0.942
February ..	4.908	2.9	7	26.18	0.782
March.	5.219	3.5	10	19.19	0.605
April.	4.630	2.6	7	28.93	1.079
May.....	4.536	3.0	8	26.31	0.700
June.....	4.534	4.0	9	22.73	0.474
July.....	4.530	5.3	12	15.95	0.356
August	4.743	4.9	13	13.42	1.355
September .	4.493	5.4	13	13.49	0.342
October....	3.910	3.6	7	22.07	0.528
November .	3.482	2.7	5	32.36	0.763
December..	3.887	2.2	3	47.79	1.217
Average .	4.418	3.5	7.6	25.17	0.679
1908					
January ...	4.214	2.9	4	43.12	1.117
February ..	4.910	2.2	5	37.06	1.063
Average .	4.562	2.55	4.5	40.09	1.009

Table XI shows the amounts of coagulant used and effect of filtration on the water.

Our highest raw water colors occur in the summer and autumn when the river is lowest, and at these times the color is also subject to considerable variations, necessitating careful watching of the raw water and regulation of the amount of alum used. The maximum raw water color (day's average color) was 140, and the minimum, 38.

The turbidity of the raw water is, as a rule, low. One day has shown a turbidity of 200. The minimum was 1; the average since the plant has been in operation, 10.

The alkalinity of the raw water has varied widely from a maximum of 80 to a minimum of 14. In 1905 the average raw water alkalinity was 39; in 1907 it was 28. There are, at times, from 1 to 5 parts of "suspended alkalinity" in the water, the exact source of which we have not been able to learn. In the earlier years of the operation of the plant it was never necessary to add alkalinity to the water except for a week or so in the spring when the snow was going off, but in 1907 it was necessary to add alkalinity (soda-ash) during parts or all of seven months — March, April, and May in the spring, and September, October, November, and December in the fall and winter.

It will be noticed that the amount of coagulant was increased greatly in the winters of 1906–7 and 1907–8. This was due to the greatly increased number of bacteria in the raw water as shown in Table VII. Ordinarily sufficient alum to reduce the color to a satisfactory amount, below 10, is more than enough to guarantee the hygienic efficiency of the plant, so that we can regulate our alum feed according to the color of the raw water.

From the time the plant was put into operation until the first of March, 1908, there have been tested at the plant 14 474 samples of water, including about two hundred fifty samples analyzed in connection with investigations of the pollution of the river. Samples of raw and filtered water are taken every four hours throughout the twenty-four for chemical and physical tests. Bacterial analyses are made daily except Sunday. These show that the bacterial efficiency of the plant is good and that the removal of coli is general also.

TABLE XI.

Month.	Color.		Turbidity.		Alkalinity.		Coagulant Used.	
	Raw.	Filtered	Raw.	Filtered	Raw.	Filtered	Pounds per Million Gallons.	Grains per U. S. Gallon.
1904								
Oct.	103	15	18	0	28	14	376	2.63
Nov.	64	7	7	0	31	17	257	1.80
Dec.	51	8	4	0	35	19	242	1.69
Av.	72	10	9	0	31	17	291	2.04
1905.								
Jan.	53	8	5	0	40	24	238	1.67
Feb.	47	9	3	0	35	19	234	1.64
March	44	10	12	0	37	21	261	1.83
April	57	6	22	0	23	9	244	1.71
May	67	11	5	0	28	14	240	1.68
June	90	14	14	0	33	15	309	2.16
July	104	13	8	0	36	14	379	2.65
Aug.	82	16	9	0	42	19	358	2.51
Sept.	80	11	9	0	42	17	352	2.46
Oct.	80	9	9	0	47	20	351	2.46
Nov.	77	10	8	0	49	22	349	2.41
Dec.	52	9	8	0	56	34	242	1.69
Av.	69	11	9	0	39	19	296	2.07
1906.								
Jan.	51	7	23	0	54	37	257	1.80
Feb.	48	10	9	0	44	28	260	1.82
March	42	6	13	0	41	25	259	1.81
April	44	3	16	0	33	22	235	1.64
May	51	8	12	0	29	22	215	1.50
June	73	10	11	0	34	23	300	2.10
July	87	9	9	0	38	24	346	2.42
Aug.	79	11	5	0	42	22	364	2.55
Sept.	75	9	2	0	27	9	356	2.49
Oct.	74	13	7	0	34	17	322	2.25
Nov.	64	9	18	0	36	20	322	2.25
Dec.	60	7	9	0	35	19	323	2.26
Av.	62	9.5	11	0	37	22	297	2.11
1907.								
Jan.	56	4	22	0	29	11	325	2.26
Feb.	45	4	8	0	29	10	361	2.53
March	47	1	19	0	29	9	414	2.90
April	56	0	22	0	27	18	363	2.55
May	61	0	10	0	29	12	364	2.55
June	65	2	5	0	29	11	348	2.44
July	87	8	3	0	30	11	358	2.51
Aug.	84	14	6	0	33	13	354	2.48
Sept.	89	12	7	0	30	10	365	2.56
Nov.	87	7	12	0	24	11	363	2.56
Dec.	71	5	14	0	28	15	366	2.57
Av.	69	5	11	0	28	12	362	2.53
1908.								
Jan.	54	1	4	0	30	14	358	2.51
Feb.	56	4	9	0	29	13	376	2.64
Av.	55	2.5	6.5	0	29.5	13	367	2.57

Full records of the operation of the plant are kept. The filter attendants are required to keep an hourly record of the amount of coagulant used, the quantity of water entering the plant, the amounts of water in the coagulating basins and clear water well, the losses of head on the individual filters, and full details of all washings of the filters. These are all checked up daily by the superintendent of the plant, who also keeps records of all water quantities passing through the plant, the amounts used in washing and waste, the amount of water pumped into service, the amounts of water on hand at the end of the day in each of the various basins, the amounts of coagulant used and on hand, and full records of the bacteriological, chemical, and physical tests made on the water.

Besides the superintendent there are three filter attendants, each working an eight-hour day.

The plant also possesses an alum storehouse capable of holding six months' supply of alum if need be. This was deemed advisable as the rigor of northern winters sometimes interferes materially with freight traffic.

The cost of operation of the plant since it started has been as given below in Table XII.

TABLE XII.

Chemicals	$13 924.52
Salaries and supervision	12 607.55
Repairs, new sand, extra labor, grading, and new construction	1 889.05
Coal	1 102.83
Freight, cartage, and miscellaneous	1 035.45
	$30 559.40

This makes the cost of filtration per million gallons, without allowing for depreciation and interest on the capital invested $5.57.

DR. E. S. WILLARD * (*by letter*). I have not had an opportunity to read this paper carefully, but from my knowledge of Dr. Soper and his work I have no doubt that the epidemic and the campaign against it have been accurately described. This is, in fact, the only account of the outbreak which has appeared, so far as I know.

It may be of interest to state that the general course followed by the city of Watertown in its crusade against the fever was in

* Health Officer, Watertown, N. Y.

accordance with a suggestion made by Dr. Soper himself several months before the epidemic broke out. When we first realized that an epidemic might be upon us and that extraordinary measures might be necessary to put a stop to it, I remembered a paper which I had heard read at the third annual conference of Health Officers of New York State, at Albany in October. The title of this paper was "The Management of Typhoid Fever Epidemics," * and it was delivered by Dr. Soper soon after he returned from the typhoid epidemic at Ithaca.

Many of the steps which should be taken to put a stop to an epidemic of typhoid were described in the paper. It was pointed out, however, that the details suited to every situation could not all be described and that the best thing for a local board of health to do in case of epidemic was to call on the state for an expert to come and direct the sanitary campaign. If the state could not supply such a person, an outside expert should be called upon. To quote from the address, Dr. Soper said:

"I am aware that in expressing an opinion favorable to what may be considered a state management of epidemcis I am recommending a course which appears to be different from that ordinarily followed in this commonwealth. But the difference is more seeming than real. It has been the custom on occasions of severe epidemic for the State Department of Health to send a representative to investigate the cause of the trouble and to recommend measures for the elimination of the cause. The visit of the expert has usually been brief, two or three days ordinarily being considered sufficient for his investigation.

"The suggestion that I make is that the state send a representative to remain long enough at the seat of epidemic to insure the adoption of measures which will bring it under control, whether this takes three days or three months."

When the epidemic began at Watertown, the State Department of Health was informed that typhoid was prevalent and a question was asked as to what, if anything, should be done about it. In response to this appeal the state sent Professor Landreth, who made an investigation into the cause of the epidemic and gave much good advice but whose other duties would not permit him to remain continuously at Watertown to fight the epidemic to a finish. There then remained the second alternative to consider,

* *Medical News*, New York, January 2, 1904.

namely, for the city to employ an independent expert. This was done by engaging Dr. Soper. He came within forty-eight hours and remained with us two months.

From first to last the relations between the state and local boards of health were cordial and, as far as the city was concerned, satisfactory. Dr. Soper acted in an advisory capacity, strengthening and supplementing the board with the results of his special training and experience and taking charge, as far as legal restrictions would permit, of a large amount of the executive work which was involved in carrying out his recommendations. The activities of the board were, of course, greatly increased in scope and number. No new laws or special ordinances were passed. The theory was that there would be enough sanitary regulations to meet the case if those already enacted were properly enforced. After the campaign was over the board returned to its usual and customary operations.

MR. M. N. BAKER* (*by letter*). It seems a great pity that Watertown, Ithaca, and Butler did not have the services of Dr. Soper before instead of after their typhoid fever outbreaks. It is certainly to be hoped that the time is not far distant when communities of this size and larger will each and all have in their employ scientifically trained men of experience and tact who will constantly guard them against both epidemic and endemic preventable diseases.

The slowness of both the city and state authorities to act at the time of the Watertown outbreak seems almost unaccountable. The State Health Department was not called upon until January 30, after some two hundred cases of typhoid had been reported within the month. The representative of the State Health Department did not arrive in Watertown until February 8, and even then he seems to have done little but give some general advice, after which he hurried away, to go back later for another brief visit.

The local authorities seem to have made no use whatever of the rules for the protection of the water supply formulated by the State Health Department. Why not? Their failure in this respect, and the apparent failure of other communities to make any very great use of like rules, suggests the utter inadequacy of this plan

* Editor *Engineering News*, New York, N. Y.

for protecting public water supplies in the state of New York. In the case of so large a drainage area and so small a community as were involved at Watertown, it is perhaps too much to expect that local authorities could effectively protect themselves against pollution under such rules as were authorized by the New York statute; particularly in view of the fact that the expenses for removing or preventing pollution are placed upon the community whose water supply is to be benefited thereby.

An explanation from some source seems to be demanded of the high typhoid death-rates that have prevailed in Watertown since the filtration plant was put in operation. In the light of our present knowledge of such matters it would appear that other sanitary reforms than an improvement in the public water supply are greatly needed at Watertown.

Water-works officials ought to realize, as few of them yet seem to do, the importance of doing all in their power to see that local boards of health do some effective work in tracing each case of typhoid fever to its source of infection. If this were done many a water supply which has been otherwise put in question would be exonerated, and, far more important still, many lives would be saved.

Mr. Kenneth Allen * (*by letter*). A public calamity that affords so excellent an object lesson in the exposition of its cause and in the means taken to eradicate the evil and bring about far better conditions than previously existed may be looked upon, from one point of view at least, as a blessing in disguise. The reduction in the typhoid death-rate from an average in 1885 to 1903 of 71, and in 1904, 194 per 100 000, to 24, 50 and 37 per 100 000 the following years, is an index of the direct effect of the house-cleaning the city of Watertown went through, but the indirect effect with its saving of life in other communities is much greater.

In this connection the various means taken to disseminate knowledge concerning the epidemic and its control, by lectures and by inviting the coöperation of the Chamber of Commerce, the Department of Charities, etc., must have gone far toward stamping out the epidemic and in counteracting the unaccountable

* Division Engineer, Sewerage Commission, Baltimore, Md.

attitude of *laissez faire* which existed. It is difficult to so convince the average citizen of the necessity of boiling a suspicious drinking water that he will see to it that it is regularly done. And if, perchance, this point is gained, the chances are nine to ten that he will not insist on equally sterile water for washing dishes, brushing teeth, and drinking when traveling.

For this reason the supplying of pure spring water at a nominal cost during epidemics of this kind is a step of much importance, and should always be done when practicable. So, too, in the preparation and distribution of disinfectants, as "white liquid" and "blue liquid," with simple directions to facilitate their safe and effective use by ignorant persons, good judgment was shown.

The failure to profit by the warning of the epidemic of 1895, and the continued high typhoid rate, seem inexcusable, but in this Watertown has not shown herself different from the average community. In matters of this kind safety is only secured by the constant vigilance of some responsible authority having power to act. The most obvious person to be clothed with such authority is the health officer. But in cases of water supplies and stream pollution the offense is so often committed beyond the jurisdiction of the local authority that, as in this case, the state must be appealed to through its Board of Health, whose executive officer, as well as the local health officer, should have power to execute the laws and ordinances governing the offense without further resort to higher powers. Beyond this come in the questions connected with the pollution of interstate streams, as the Mississippi, Missouri, Ohio, Delaware, Susquehanna, concerning which disputes, if not amenable to arbitration, must be referred to some Federal authority. Such cases are becoming more and more frequent with increased densities of population, and it is quite possible they may be best handled in connection with the question of water transportation and water-power by a Federal commission independent of, but coöperating with, and coördinating the efforts of, the several departments of the government. Such a division of authority would be elastic, in harmony with the general theory of our government, and would at the same time avoid division of responsibility. Moreover, it is directly in line with the present development in many of our states.

In the Watertown case the ineffective legislation of 1896 is instructive. With laws no doubt in the main good, and with power to act, yet they were rendered inoperative by imposing an unknown but possibly very great cost on the commissioners to whom their execution was intrusted. That fatal provision blocked the way at once to any abatement of the offensive conditions, and it was only after these became alarming and the higher authority of the state stepped in that efficient results were secured.

Fortunately the city and state coöperated in harmony, the former paying the latter for sanitary work on the watershed above by special agreement. The more definitely the line of responsibility can be drawn, however, between state and local jurisdiction in such matters, the better, and it would seem as if this might be accomplished at least to a greater degree than exists at present.

MR. FRANCIS F. LONGLEY* (*by letter*). Dr. Soper's interesting paper sets forth in admirable manner the facts regarding this virulent outbreak of the dread typhoid in Watertown. It is of especial interest to the writer because of his connection with the water department of that city in charge of the operation of the filters during the year following the epidemic herein described. The filters, which were in course of construction at that time, were finished and put in operation early in the following September. They are of the "mechanical" type, and were fully described in the columns of the *Engineering Record* of dates May 21 and 28, 1904.

In watching the typhoid fever situation in Watertown during the first year of operation of the new filtration plant, the writer was impressed with one unusual fact. That was, that the typhoid death-rate fell from an average of 83 per 100 000 to 24 per 100 000 in that first year, in marked contrast to the gradual fall in typhoid death-rates in many other cities after the complete or nearly complete removal of the source of infection in the water supply.

The question that naturally arises is, What was the cause of this clean-cut drop in the typhoid curve? Was it the purification of the water supply alone, or were there other large contributing causes? The advocates of pure water and of filtration would be glad enough to take the credit for it in its entirety, but may they

* Chief Chemist and Assistant Superintendent, Washington Filtration Plant, Washington, D. C.

do this? The epidemic described in this paper was severe enough to thoroughly frighten the people of Watertown, frighten them into far greater precautions against infection by typhoid from all sources than they would have used except under the influence of such a fearful calamity. And it is logical enough to believe that these precautions that individuals took of their own free will had a very appreciable effect in preventing many cases that would otherwise have been contracted. This is not a new idea, nor is it hard to find evidence tending to support it. For instance, take the typhoid record Dr. Soper has presented for Watertown, supplementing it with the rates for the three years that have passed since the epidemic year, as shown in Fig. 13.

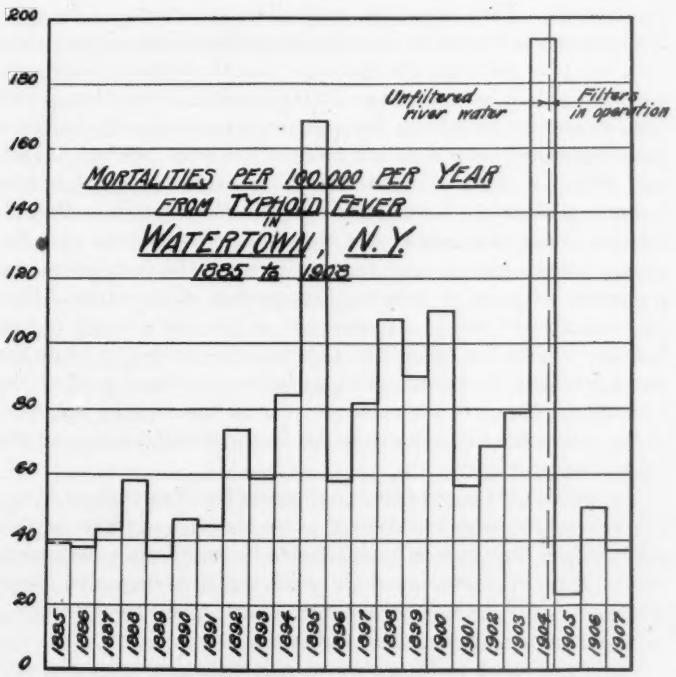


FIG. 13.

Dr. Soper speaks of the epidemics in 1895. They are very evident on this curve. Vigorous preventive measures were applied, largely through individuals. The result was that the curve for the following year dropped very low for Watertown. But it did not stay low. With the sense of security that came with the low rate of 1896, the individual seemed less impressed with the necessity for the vigorous precautions of the year before, and consequently we see the typhoid rate climbing up again.

No distinct epidemic has been noted for the years 1898–1900, but the conditions are plain, with an average typhoid death-rate for the three years in excess of 100 per 100 000. No doubt this caused a campaign, following the high rate of 1900, against the infection, with the result of bringing the rate down in 1901 to 57 per 100 000. Then again the curve rises for several years until it culminates in the epidemic which forms the subject of this paper.

In the year following the epidemic year the typhoid death-rate dropped, as is shown, to 24 per 100 000, which is lower than it had been in more than twenty years for which records are available, and considerably less than one half the low rates reached in 1896 and 1901. A mass of most conclusive evidence points to the improvement in the water supply as the large factor in this reduction of the death-rate; but is it not very probable that the preventive measures prosecuted so vigorously the year before had a decided influence in reducing that portion of the typhoid that was not affected by the improvement in the water supply? And is this not borne out by the fact that the rate jumped up again the two succeeding years, indicating as before the wearing off of the educational effects of the epidemic year in the security apparent in the minds of the public from the improved conditions and the lowered death-rates?

The curve of typhoid fever death-rates for Washington, D. C., has during the past twenty-five years shown variations of this same nature that were not explainable by any known changes in the quality of the water, and for which the ideas suggested above do seem to afford a reasonable explanation. The curves for many other cities, too, show similar variations.

There are many factors, such as meteorological, climatic, and racial conditions, as well as the questions of pure water and proper

drainage, that influence typhoid rates in ways that are too devious to follow, and there is no intention of arguing the elimination of such considerations nor of pretending to dismiss with one simple argument a question which is of the most serious complexity. This discussion is presented simply with the idea of bringing out the importance of two points: First, the educational effect upon a community of a distinctly epidemic typhoid condition, with all the object lessons attendant thereon; and second, the error that has been so commonly made in placing the entire blame for high typhoid rates upon the water supply, even when that is known to be badly polluted. It is evident enough that the degree to which the water supply alone may be blamed varies with the amount of pollution; but even assuming this to be a very considerable degree, the other causes tending to produce typhoid are generally not insignificant, and they should not be overlooked, as has so often been done.

A great deal has been said upon the subject of typhoid fever in Washington since the installation of the filtration plant nearly three years ago. This city had long been afflicted with a high typhoid rate, and the water supply, drawn from the Potomac, had been blamed for it. Naturally all agreed in predicting a great reduction in the typhoid with the use of the purer water supply. And naturally all were disappointed and mystified upon seeing the typhoid appear with no diminution in quantity or intensity during the first year of operation of the filters. This had the effect of bringing down much unfortunate and sensational criticism of the water supply, and the new filters were advertised far and wide as a failure.

The results of the studies on the quality of the water, both before and after filtration, the results of investigations that have been carried on for two years by the Public Health and Marine-Hospital Service, the close consideration of the problem by the health department of the District of Columbia, the deliberations of the Medical Society of the District, and the opinions quite unanimously formed by the many sanitarians and experts who have given this subject their consideration, all point to the conclusion that the early assumptions were wrong. The filters were not a failure, but were doing most excellent work. The advent of

filtered water did not cause a marked and prompt reduction in typhoid because the Potomac water was not a large factor in the causation of the disease. The importance of certain other factors, which had before been neglected in favor of the polluted water theory, was accepted and emphasized.

When, years ago, the relation was pointed out between polluted water supplies and typhoid fever, and emphasized by epidemic after epidemic of the most virulent nature, with the most convinc ing evidence to prove this relation, the dangers lurking in polluted water were preached far and wide; and in the light of the evidence adduced, the theory of water-borne typhoid was almost universally accepted.

This was right and proper. The facts in a great many spectacular outbreaks of typhoid fever have been so closely in accordance with this theory as to eliminate every doubt of its application to the cases in question. There is an element of danger, however, in the too complete acceptance of this theory. There is danger of forgetting almost entirely that the disease may have its origin in many other causes. In their highly commendable enthusiasm over the application of this theory, some of the ablest writers in the country on sanitary subjects have entirely ignored this possibility. And therefore it is that the writer wishes to comment in this way upon the too complete acceptance of the water-borne typhoid theory to the exclusion of other factors, the importance of which has been underestimated. Engineers know without question how to eliminate the typhoid that is carried through water supplies; and there the function of the engineer ceases, or rather merges in with that of the municipal official upon whom falls the burden of dealing with that part of the typhoid which has been called "residual." The indications seem to be that in some communities this "residual" typhoid may be a large part of the whole, and the need of greater knowledge in regard to it is evident. In connection with some problems it has been thoroughly studied with promising results in some directions, though less so in others, but it should be persisted in without discouragement.

The importance of education in this subject of typhoid has been mentioned. An epidemic is a good means to that end, but it is an expensive and heart-rending, as well as an impressive ex-

perience. Education through the medical fraternity seems logical for this subject, but it has been found unsatisfactory and ineffective. The same is true of bulletins, circulars, and newspaper publicity. But could any means be found more satisfactory than through the public schools? For the subjects of study of the school children, if of human interest, very quickly become the subjects of discussion and perhaps of further study in the home. They need not be technical; the less technical, in fact, the better. There are a few admirable books that would answer the purpose, and the writing of others awaits only the creation of the proper demand.

The writer is inclined to offer an apology for dwelling upon topics that lie more strictly within the realm of education and of medicine, but while they are of little value to a superintendent in checking waste, or to an engineer in the selection of pumps, they are pertinent in the discussion of a subject which concerns us all, as this does.

One other point the writer wishes to refer to is a case of gross carelessness in the pumping station at Watertown. The regular intake extends, as Dr. Soper has stated, to a settling basin. During the construction of the filters and the extension of the intake to the new plant and coagulating basin the city supply was drawn partly through an emergency supply pipe directly from the flume along the east side of the building. About 50 or 60 feet above this emergency intake, and situated within the pump-house, was the toilet-room jutting out over the flume, a splendid opportunity for another spectacular outbreak of typhoid by a very direct transmission of infectious material, only wanting the proper individual, and disgusting from its evident proximity. Inquiry failed to reveal any one who had suffered from the fever, and who had worked in, or frequented the pump-house. The danger from this source was eliminated, of course, when the proper intake to the new filters was put in service, and later the toilet-room itself was removed. But it is an example of the dangers that may lurk right under the official eye and escape detection in the general search that is made for sources of pollution.

Dr. Leonard P. Kinnicutt * (*by letter*). No one can read Dr. Soper's most interesting and instructive paper on the 1904 typhoid

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

epidemic at Watertown, N. Y., without feeling how great are the strides made by epidemiology during the past two years, and how differently a typhoid fever epidemic is handled to-day than it would have been yesterday.

Yesterday we sought for the primary cause and, finding it, we contented ourselves with an attempt to prevent further spread of the disease from the original source, leaving almost untouched all secondary causes. To-day it is considered that unless all possible means are used to prevent the indirect spread of the disease, comparatively little has been done.

Koch's investigations at Triers showed that for the prevention of the spread of typhoid fever almost as great precaution must be taken as is the case with scarlet fever or diphtheria; and possibly the most interesting part of Dr. Soper's paper is the description of what might almost be called the extreme measures that were used at Watertown to prevent all possible sources of danger of the infection being carried from person to person; and to those familiar with city governments it shows what "courage of conviction" is able to accomplish; and there is no question that the work of Dr. Soper will be of great use and make the work of the epidemiologist in the future much easier in persuading city officials that only by the most thorough measures can an epidemic of typhoid fever be stamped out.

Possibly one point in Dr. Soper's paper that is not sufficiently dwelt upon is regarding the closing of all suspicious wells. This, of course, may have been done at Watertown, though the statement that the result of the examinations of the wells showed that the water of most of them was of an unsatisfactory quality, yet only in a few cases were the wells ordered closed, leaves the question somewhat in doubt. In times of epidemics it would certainly be best to close all wells which gave any indication of pollution.

Dr. Soper, in speaking of the mechanical filtration plant which was in course of construction at the time of the epidemic, gives the typhoid fever rate since it was put in operation, in 1905, 24 per 100 000; in 1906, 50; and in 1907, 37; but makes no comment on these figures. Professor Sedgwick, in referring to them and to the continued typhoid at Washington since the slow sand filters were put in commission, states that in his belief it is due to residual

typhoid or to typhoid due to other causes than the public water supply. Not questioning at all the fact that typhoid is due to other causes than polluted water, is it not possible that the prejudice of the French sanitarians against filtered water and the present tend in Germany to the development of ground waters as a source of supply is not without justification?

DR. M. J. ROSENAU * (*by letter*). In addition to the many excellent features of Mr. Soper's report, one is especially impressed with the fact that Watertown got off very cheaply. The efficient and energetic measures adopted to suppress the epidemic were put into effect at a small cost, compared with the price of life and health. Watertown owes to the sanitarian a debt of gratitude. Ordinarily it takes a catastrophe to stimulate a community to adopt vigorous sanitary measures. It is a matter of much regret that cities suffering with residual typhoid, or with typhoid in what might be called the *status epidemicus* cannot be stimulated to adopt vigorous suppressive measures.

DR. SOPER. Among the many interesting questions raised in the discussion of this paper, there is one upon which there is substantial agreement. All agree that typhoid must be regarded as not merely an infectious disease, but as one that is contagious as well. The fact that a public water supply must not be alone held responsible for cases of sickness in an epidemic like that at Watertown is recognized by all. The general acceptance of this view is peculiarly agreeable to me since, as Professor Sedgwick says, my convictions with respect to this point have strongly influenced my work for the last five years. That the plan for the Watertown campaign has met with approval at the hands of the very experts whose opinions I most value is very gratifying.

There never was any doubt in my mind as to the effectiveness of the work. To stop the epidemic a sum approximating $25 000 was spent in two months. The epidemic had been running without abatement for two months. Within two weeks after the measures of suppression were put in force, the number of new cases each day diminished to about one half, and although the epidemic continued for nearly two months longer, its intensity never again increased, but diminished steadily to the end. If the table given in the body

* Public Health and Marine-Hospital Service, Washington, D. C.

of the paper showing the number of cases reported daily does not indicate the effectiveness of the suppressive measures, I am at a loss to comprehend to what cause the diminution is to be attributed.

The only regret is, as Mr. Baker has pointed out, that the work of stamping out this epidemic was not begun earlier; that it was not, in fact, made unnecessary by preventive and remedial sanitary measures applied to the water supply years before. Health Officer Willard in his discussion has explained why some valuable time was lost. Acting on advice which I myself had given in a paper read before the assembled health officers of New York state some months previously, the city of Watertown applied to the New York State Department of Health before seeking help from outside sources. Had the state responded to the call with the promptness and thoroughness which the situation demanded there is no reason why the city should not have had relief three weeks earlier. The delay in calling upon the State Department and the indifference with which the citizens had continued to drink polluted water from the Black River for so many years prior to the epidemic can only be attributed to apathy, an apathy which, as has been pointed out by Mr. Whipple, is not peculiar to Watertown. Apathy toward typhoid exists everywhere in the United States.

The personal element enters into the cause of typhoid fever to a far greater extent than is commonly understood, for typhoid is transmitted from one person to another not only in epidemics, but at all times. The cause of this personal transmission is due, in the last analysis, to individual ignorance and indifference.

The time has passed when a single channel of transmission like a public water supply should be held accountable for all the cases of typhoid which occur in an outbreak. The possibilities of transmission from persons who are sick and from healthy bacillus producers are sufficient to account for many cases in every epidemic. I believe that practically all sporadic or prosodemic typhoid is produced in this way. Only by preventing typhoid from spreading in this way can we hope to eliminate it utterly. As Professor Sedgwick says, typhoid is commonly looked upon as infectious and not contagious. It is too often regarded as transmissible in only one way in an epidemic, as by water, for example. This is a mistake.

A point to which Professor Kinnicutt has alluded, and which

was apparently not made sufficiently clear in my paper, is the danger which is to be apprehended from local foci other than strictly personal ones. Wells belong to this class. There is no doubt in my mind that in typhoid epidemics, wells which are ordinarily only polluted sometimes become infected with typhoid germs and give rise to cases of typhoid which are attributed to the main source of infection. I found in the epidemic at Ithaca a well of this kind. The well had long been regarded as pure, and when the public learned that the city water supply was dangerous, as many people as possible turned with confidence to the well for their drinking water. So great was this confidence, and so large the demand on the well, that the water was piped from the private property upon which the well was located to another house in the vicinity. At first no trouble resulted. But toward the end of the epidemic a case of typhoid occurred in the house where the well was located. The attending physician did not recognize the sickness as typhoid, and the dejections were allowed to pass without disinfection through the sewer. The sewer was defective and the bacilli entered the well, producing fifty cases of typhoid with five deaths.*

The danger from wells was constantly guarded against at Watertown. Wells located on private property and in mills were examined with much care by means of analyses and inspections. One of the objects of the laboratory was to examine the waters of the wells. At Ithaca 946 private wells had been examined under my direction, and at Watertown, although there were fewer wells, the work was no less thorough. The people were warned against the use of wells whose purity rested merely on common repute. It was generally necessary to present convincing evidence of danger in order to prove that the well was polluted, for people in small cities are as loyal to their wells and privies as though they were members of the family. But once the danger was made plain, a family would willingly abandon its well. Few wells were formally ordered closed for this reason. The object of the spring water supply distributed by the Board of Health was to cut off the need of using the public water and the private wells as far as practicable.

* "The Epidemic of Typhoid Fever at Ithaca, N. Y.," by George A. Soper, Ph.D., JOURNAL of NEW ENGLAND WATER WORKS ASSOCIATION, Vol. XVIII, No. 4, pp. 445–446.

I feared contamination of the milk supplies, for it is not uncommon in an epidemic like that at Watertown for country people who are attacked during temporary residence in the city to go back home to be nursed through typhoid. One case of typhoid in a dairy might very possibly cause many others. Here was a danger which it is extremely difficult for a city like Watertown, when afflicted by epidemic, to guard against. The farms which supply the milk are likely to be miserably dirty. To at once raise them from their filthy state to such a condition of sanitary excellence as to exclude the danger that the milk may become infested with typhoid germs is impossible. I am confident that in some of the long and intense typhoid epidemics which have afflicted American cities, milk supplies have become foci of typhoid germs long after the original cause of the epidemic has ceased to act. At Watertown the Board of Health sought to combat this danger by warning the public against drinking raw milk and by exercising such supervision as was practicable over the sources of the milk. It is proper to say that these precautions were not as thorough as was desirable, but no milk supply was found to be contaminated.

Along with such foci as water and milk belong dangers incident to the consumption of fruit and other food which are handled and exposed for sale within an infected city. At Watertown an Italian fruit dealer who was found to be harboring a case of typhoid in his establishment was given the choice of closing his shop or having the patient removed to hospital.

Mr. Whipple has said that the original source of the infectious matter seemed to be less effectively guarded against than the local sources. This criticism is, in a measure, just. The public water supply was, in my judgment, so heavily polluted that no measures intended to exclude or remove the polluting matters would be at all likely to prove successful. It seemed to be a sheer waste of time and money to attempt to " clean up " the drainage area, as is so often attempted in epidemics. Two months of spring weather probably had done much more than human effort could do to remove all the defilement which it was practicable to remove.

On this point there was, as pointed out in the paper, a clear division of opinion between the state department of health on the one hand and the city department of health on the other. It

was not doubted by either that the typhoid epidemic had been brought upon the city by the water and that permanent sources of pollution still existed upon the river. But it seemed to me impracticable to do away with these sources. Because of the great expense involved it had been impossible for the water board to avoid them by enforcing the state law. The drainage area was extensive and at several places villages and mills crowded the river banks, and even islands in the river were built upon. Several sewerage systems were discharging into the stream when the epidemic broke out. These sewerage systems could not be eliminated. So far as typhoid was concerned, it was necessary first to find the infectious matter before it could be removed. The investigators available for this undertaking were such young men as happened to be out of employment and could be induced to take up this work. They knew nothing of sanitation. The inhabitants of the drainage area were by no means all on friendly terms with the city and it seemed undesirable to earn their hostility by a clumsy interference with what they had long considered were their rights. The details of the procedures which should be followed in the event of a case of typhoid being discovered were by no means well defined. Obviously they should vary with circumstances. The best that could be done would be to trust to the judgment of the inspectors. In view of the fact that the city had its hands full in guarding against local sources of infection, it seemed far better to leave the cleaning of the drainage area to the state department of health, place emphasis upon the fact that the river water was dangerous and must remain so, and at the same time place within the reach of all an abundant source of water of unquestioned purity.

At the same time, by special arrangement with the authorities at Deferiets, a number of cases of typhoid in that village were taken off the sewerage system and provision was made for disinfecting and disposing of the excreta in a sanitary manner. The hospital facilities at Watertown were extended, as always, to the country people. The laboratory facilities of the Watertown Board of Health were placed at the disposal of all physicians on the drainage area for the discovery of typhoid cases and of people who were not sick but who were unconsciously producing typhoid

bacilli. In this way a little boy was discovered who had recovered from typhoid and who was being sent to school in one of the villages on the river above Watertown with urine literally clouded with typhoid bacilli.

With so many possible sources of typhoid within and near the city, it is not strange that the epidemic, once started, should have been of long duration. In fact, it is not clear why typhoid should ever be completely stamped out without careful, skillful, and long-continued effort. In some epidemics it seems not to stop until every susceptible person is attacked.

The danger of an indefinite continuance of typhoid seems the greater when we consider the part played by healthy bacillus carriers in the dissemination of the disease. In the case of a chronic bacillus carrier whom I happened to discover in 1906, seven separate household epidemics were produced over a period of five years, a record which probably would be increasing to-day were it not that the unfortunate person who was producing the germs was taken into custody by the New York City Department of Health and detained as a menace to the public health.* In numerous occurrences of typhoid in Germany, and in a notable outbreak just reported by Dr. R. M. Buchanan, of Glasgow, the danger of unsuspected typhoid bacillus carriers in dairies, and wherever food is handled, has abundantly been set forth.

The bearing of all these facts upon typhoid is evident. Residual typhoid no longer necessarily means, as we all understood the term to mean when Professors Sedgwick and Winslow originally proposed it, the typhoid which remains in a city after the public water supply has been perfected. It may mean the typhoid which remains when the sources which lie within the city have been satisfactorily eradicated and only the water supply remains open to suspicion. In many instances these proximate sources may alone be to blame. The experience of Washington, and the thoughtful remarks of Mr. Longley in connection with this subject, well illustrate the necessity of taking advanced ground in accounting for the presence of typhoid fever everywhere.

As Professor Kinnicutt has said, great progress has recently

* "The Work of a Chronic Typhoid Germ Distributer," by George A. Soper, Ph.D., *Journal of the American Medical Association*, June 15, 1907.

been made in our understanding of the cause of typhoid, and the opinions of yesterday are no longer those of to-day. But there still remain some obscure problems connected with this subject. I agree with Professor Winslow in believing that we are only at the beginning of our knowledge of typhoid, and I cannot share Mr. Whipple's view that the ways in which the typhoid germ is transmitted and the ways of preventing this transmission are all well understood. I hope the knowledge of to-morrow will be considerably in advance of the knowledge of to-day.

Mr. Allen has raised an interesting question. He has called attention to the fact that typhoid epidemics are sometimes highly educational, and he and Mr. Longley have remarked that the sanitary instruction, coupled with the alarm which people experience at such times, apparently cause them to exercise precautions that, for a few years at least, after the epidemic, protect them to a considerable extent against typhoid. With this view I am in general agreement. But I cannot think that greater precautions alone account for the fact that in the year or two following an epidemic there is likely to be much less typhoid than previously existed. I think other forces are at work also.

Why Watertown has had so much typhoid since its epidemic of 1904, I am unable to explain. Mr. Jennings suggests that it is because the country people in the vicinity use the city hospitals, and Mr. Whipple gives a number of reasons for thinking that the filter plant is not to blame. On the other hand, Professor Kinnicutt plainly intimates that he is not perfectly assured of the infallibility of filters. Mr. Longley apparently thinks the disease is being spread through lax sanitary precautions. This point is an extremely interesting and important one, but I confess I know nothing whatever about the persistence of typhoid in Watertown since the epidemic. I agree in thinking this question should be cleared up.

An obscure point in the epidemiology of typhoid is the fact that strangers are more likely to be attacked on visiting a typhoid city than are the customary residents. At Ithaca typhoid was prevalent for years among new students at Cornell University. So disproportionately large was the number of freshmen attacked that the disease which filled the infirmary every fall was called

"freshman fever." Troops sent to a distance are said to be much more liable to typhoid soon after reaching their destination than subsequently. Similarly, typhoid epidemics appear to be most intense in places where the people have previously suffered least from that disease. It is possible that the epidemic at Watertown would have claimed more victims at the outset had the water supply not been so contaminated and typhoid so common in other years. Does continued exposure to the germs always either produce typhoid fever or confer immunity? There is here a most interesting field for research.

It is difficult to account for the obscure question of the seasonal distribution of typhoid to which Professor Winslow refers. Excluding epidemics due to surface water supplies, typhoid is, in northern countries, chiefly a disease of autumn. I believe that people are more exposed to typhoid germs at this season than at any other. At this time people are moving about the country more freely than at other seasons, exposing themselves and others to an unusual extent. Probably people are more susceptible to typhoid in the autumn. This may be because of changes in diet, or it may be because of certain unusual metabolic conditions due to changes in temperature. Certainly personal susceptibility changes from day to day and it probably varies from season to season.

Is it not possible that the difference in seasonal incidence of typhoid among Indian and British troops mentioned by Professor Winslow may be due to some difference in personal habits? I cannot think that the temperature of the summer or early autumn has any material effect upon the vitality or virulence of the typhoid organism outside of the body, or that the weather directly affects one class of men in one way and another in an opposite way. I am inclined to believe that the causes which lead to the prevalence of typhoid in the autumn are due to (1) greater personal susceptibility; (2) greater exposure to the germs.

Before attempting to explain what appears to be the excessive prevalence of typhoid in some American states as compared with others, I should like better assurance of the correctness of the statistics. It is a cause of just reproach that vital statistics are so inaccurate in America. Even the statistics of deaths are unreliable in our most enlightened states, and this being so, what

reliance can we place upon the reports for the whole country? In the masterly investigations made into the causes of typhoid fever among the American troops in the Spanish War, Drs. Reed, Vaughan, and Shakespeare considered that not over 50 per cent. of the typhoid cases were discovered by the average civilian physician. This is not denying, however, that typhoid is more prevalent in warm countries than in northern ones. There is much evidence to support the interesting point raised by Professor Winslow.

Mr. Allen and Mr. Longley, Mr. Whipple and Mr. Baker, have urged the necessity of official action in respect to the control of typhoid fever, and the suggestions which these gentlemen make are worthy of most careful consideration. There is need of defining city and state limits of supervision over the pollution of streams; there is need of really useful state rules for the protection of surface water supplies; water boards should insist that boards of health trace typhoid cases to their sources. Physicians should report their cases of typhoid. It is high time that the principles of sanitary science applicable to the prevention of typhoid were recognized by educational authorities and taught more rationally and effectively in the schools.

As Professor Sedgwick has eloquently and forcibly pointed out, the keynote to better work in the prevention of typhoid lies in adopting higher standards of living. Higher standards should be established in every branch and department of public health work, including the conduct of public water supplies. The adoption of higher standards can alone eliminate typhoid.

Typhoid will continue to be prevalent so long as indifference toward it continues. The tribute which the American people are paying for this indifference is the loss of not less than 20 000 lives, $150 000 000, and the heart-rending miseries which are entailed by over 300 000 cases of typhoid annually.

THE TROY WATER WORKS EXTENSION.

BY E. L. GRIMES, CITY ENGINEER, TROY, N. Y.

[*Read March 11, 1908.*]

HISTORICAL.

The city of Troy is located on the easterly bank of the Hudson River, at the head of navigation. It occupies the river plain for a distance of about six miles north and south and extends back upon the hills to the eastward from one to two miles. The river plain has a general elevation of about 30 feet, while the hills occupied on the east rise to elevations of from 300 to 500 feet above tide-water. At the time the water works system was first undertaken, the city had a population of about 12 000; it now has a population of about 77 000.

The Troy Water Works Company, a private concern, was incorporated by act of the Legislature, April 18, 1829. This company intended to supply water for domestic purposes only and seems to have accomplished very little.

About a year after the company above referred to was incorporated, the Common Council of the city passed a resolution creating a committee with instructions to make surveys, plans, and estimates for bringing " a suitable supply of good water " into the city. On August 11, 1830, this committee reported upon two plans, — one to take water from the " Gorton Springs," at an estimated cost of $60 000; the other to use the " Piscawen Waters," at an estimated cost of $80 000.

In May of the following year a committee was appointed to see what arrangements could be made with the Troy Water Works Company to supply the city with water for extinguishing fires, watering streets, etc., and to learn upon what conditions the company would transfer its charter rights to the city, provided the necessary legislation could be obtained. The committee reported, March 26, 1832, that they could not make satisfactory arrangements with the Troy Water Works Company for the supply required,

but that the company had agreed to surrender its charter to the city upon the payment of the amount actually paid out by them, $174.34. The committee further reported that the legislature had already passed the necessary bill for the transfer, by an act entitled," An Act in Relation to the Troy Water Works Company and for insuring the City of Troy a Supply of Water for the Extinguishment of Fires and for Other Purposes."

Acting upon this report, the Common Council ordered a house-to-house canvass to be made to ascertain the sentiment of the people in regard to the matter. As a result of this canvass, it was found that 637 were in favor, 8 opposed, and 18 indifferent to the project. One hundred and seventy-eight agreed to take water when it was brought into the city.

Surveys for the construction of the reservoirs upon the Piscawankill were begun in March, 1833, and contracts for the work were immediately made. A contract was also made with Samuel Richards, of Philadelphia, to furnish cast-iron pipe and castings at the following rates delivered in Troy: 12-inch, $1.85 per foot; 10-inch, $1.50; 8-inch, $1.30; 6-inch, $0.90; 4-inch, $0.50; 3-inch, $0.40 per linear foot, and branches and other castings, $62.50 per ton.

The works were completed in 1834 and consisted of a diverting dam across the Piscawankill; two open and one covered reservoirs, having a combined capacity of about 1 000 000 gallons, and a 12-inch main leading from the covered reservoir to the city. The ruins of these old reservoirs are still to be seen just easterly of the Boston & Maine Railroad near Eddy's Lane.

The work had been completed but two years when it became evident that some means should be devised to increase the supply. In 1839 land was purchased and a dam known as the Fire Dam was built for the purpose of storage upon the site now occupied by the low-service distributing reservoir. This reservoir appears to have been insufficient, for the next year the committee in charge suggested pumping water from the Hudson River.

The idea of pumping seems to have been abandoned for some reason, and in the fall of 1840 the right was obtained to erect and maintain a dam at the site now occupied by the dam of the Brunswick reservoir for the term of two years, with the privilege of

buying the property outright at the end of that period if the city elected to maintain a permanent reservoir at that point. The dam was built and all the property rights were later acquired.

The full development of the Piscawankill watershed as a water supply was finally accomplished by building the present " Upper Oakwood " reservoir in 1859–1860, the " Lower Oakwood " in 1861–1862, and the " Vanderheyden " reservoir in 1868. These reservoirs, together with the " Brunswick," gave a total available storage capacity of about 281 000 000 gallons.

In 1872, Wm. J. McAlpine, civil engineer, who was employed to examine all the feasible sources of water supply for the city of Troy, and report on the cost of procuring the same, made a report in which he suggested five sources of supply, namely, the Tomhannock, the Poestenkill, the Hudson River, the Deepkill, and the Wynantskill. In concluding his report, he says: " The Tomhannock plan possesses advantages over all of the others in the economy of its cost and the purity of its water, and is equal to any of the others in the abundance of water." None of the schemes suggested by Mr. McAlpine was carried out.

In 1877 and 1878, Prof. D. M. Greene, civil engineer, presented reports and plans for pumping water from the Hudson River, and in 1879 a pumping plant was built under his direction. This plant consisted of two Holly duplex pumps, each of 6 000 000 gallons daily capacity, together with the necessary intake crib in the river, a tunnel to convey the water from the intake to the suction well, and a 30-inch cast-iron force main extending from the pumping plant to the " Lower Oakwood " reservoir, a distance of about three miles.

The water was pumped from the river into the " Lower Oakwood " and allowed to flow by gravity from there to the distributing reservoir.

The low-service distributing reservoir was built in its present form in 1883, at which time a 24-inch supply main was laid from it to connect with the distributing system of the city. This line of main pipe crossed the stone arch just below the reservoir and connected with the 20-inch main of the old system near the old covered reservoir. Provision was also made at the new distributing reservoir for another 24-inch main. This was laid down

Eddy's Lane, or Glen Avenue, and Seventh Avenue to Park Street, connecting with the distributing system, in 1885.

The middle service system was connected with the "Upper Oakwood" Reservoir in 1879, and the high-service system was taken from a small new reservoir, known as the High Service Distributing Reservoir, built especially for that purpose during the same year.

The supply thus provided proved to be adequate until about 1893, when Prof. W. G. Raymond and Elnathan Sweet were employed to investigate and report upon a new source of supply. These engineers made a report upon the development of the Poestenkill and Quackenkill, two streams lying to the southeast of the city. Nothing further seems to have been done toward procuring an additional supply until 1900. In the meantime Professor Raymond's attention was directed to the Tomhannock Creek, a stream of considerable size flowing through the towns of Pittstown and Schaghticoke into the Hoosick River. He found upon investigation that a very large storage reservoir could be made there at comparatively small expense.

The Tomhannock Reservoir would not, however, be at a sufficient elevation to supply more than the low, middle and Lansingburgh services. Therefore it was finally decided to develop the Tomhannock for these services, and the Quackenkill for the high-service supply.

Authority to expend $1 250 000 for an additional water supply was obtained from the legislature in 1900, and the work was immediately undertaken under the direction of Prof. W. G. Raymond as consulting engineer.

THE QUACKENKILL.

The Quackenkill drainage area is located on the mountains east of Troy in the town of Grafton. It consists largely of grazing and wooded lands and contains several lakes of considerable size. These lakes are located in the more elevated portions of the area, are fed largely by springs, and contain water of very good quality. Streams flowing from the lakes join to form the Quackenkill. On account of its great elevation above the city it affords an excellent source from which to obtain, by gravity, an additional supply for

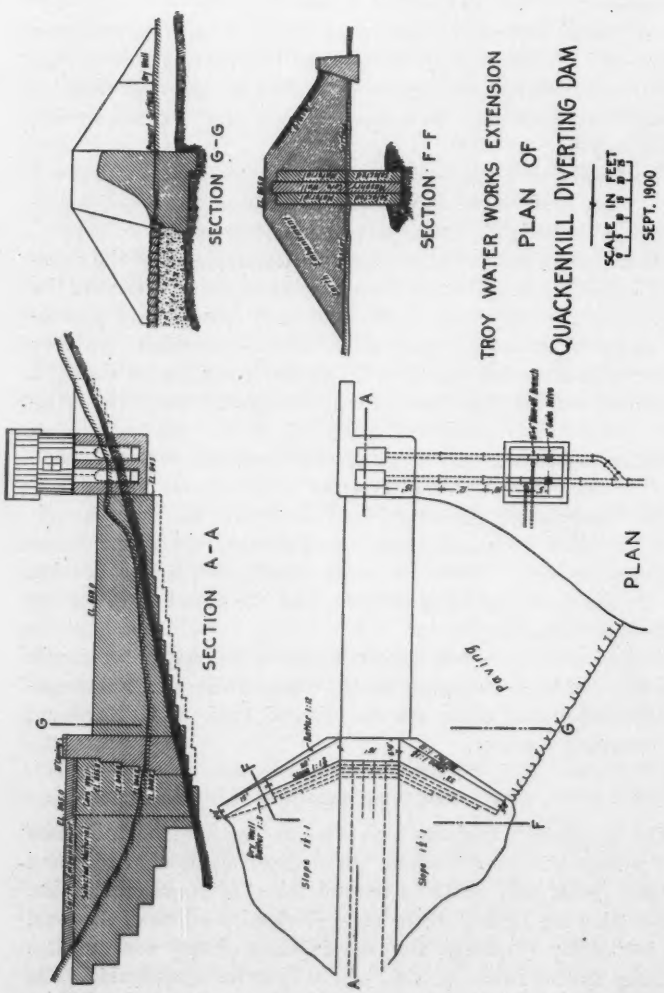

SECTION G-G
SECTION F-F
TROY WATER WORKS EXTENSION
PLAN OF
QUACKENKILL DIVERTING DAM
SCALE IN FEET
SEPT, 1900
SECTION A-A
PLAN

FIG. 1.

FIG. 1. Quackenkill Diverting Dam and Gate House.

FIG. 2. Tomhannock Dam Site with Culvert Completed.

the high-service system of the city. The original plans contemplated the full development of about 17½ square miles of the drainage area around the headwaters of the Quackenkill.

To accomplish this it was proposed to build dams at the outlets of the lakes so as to increase their storage capacity; two large storage reservoirs, one about 2 miles and the other about 5 miles below the lakes; a diverting dam near the town line between Grafton and Brunswick; one or more conduits from the diverting dam to the large storage reservoir, known as the "Brunswick," about 3 miles distant from the city; and a conduit from the "Vanderheyden Reservoir," to connect with the old high-service conduit at the old high-service distributing reservoir. Up to the present time the only work carried out under these plans consists of the building of the diverting dam, a single conduit from it to the storage reservoir, and a single conduit from the storage reservoir to connect with the old high-service main.

The diverting dam (Fig. 1, and Plate I, Fig. 1) consists of a concrete spillway and gate chamber, and an earth embankment with concrete core-wall. Although only one conduit has been laid from the dam to the storage reservoir, the proper connections, valves, etc., have been built into the dam for a second one, if it should ever be needed.

The conduit from the diverting dam to the "Brunswick Reservoir" consists of 29 550 feet of 16-inch, and 3 167 feet of 12-inch cast-iron pipe designed to have a carrying capacity of about 5 000 000 gallons per 24 hours. The outlet of this conduit is taken some distance into the reservoir, where it terminates in a bell-shaped concrete mouthpiece. This mouthpiece turns upward and serves to a small degree as an aërating fountain.

From the "Brunswick" the water passes over a weir or through pipes in the embankment into the "Vanderheyden Reservoir." A new intake gate-house has been constructed at the dam of this reservoir. It was built with hollow brick walls filled in solid with concrete. Vitrified paving brick were used below the high-water line, and ordinary hard burned building brick above that line. A 20-inch conduit was laid from this gate-house to a connection with the old high service conduit. This conduit is 9 000 feet in length and gives an additional static head of about 90 feet.

It also eliminates the possibilities of contamination, which so largely existed in the open channel, through which the water formerly flowed.

THE TOMHANNOCK.

The Tomhannock drainage area is located northeasterly of the city and comprises above the reservoir dam an area of 67.3 square miles. The surface is very uneven, being of a rolling or mountainous character. It is largely a farming district, only about 15 per cent. of the area being covered with forest growths. There are about 600 houses on the drainage area and a resident population of about 2 500, or 35 people per square mile.

The location selected for the reservoir is about 10 miles northeasterly of the city. Here the valley of the Tomhannock, for a distance of 5 miles, has an average fall of about 8 feet per mile and an average width of about three quarters of a mile. At the point selected for the dam, the hills on either side of the valley approach each other until only a narrow ravine lies between them.

The hills surrounding this valley are of a shale formation with only a thin covering of earth. The valley is covered with glacial drift a few feet in depth, with here and there a deposit of considerable magnitude. Bed rock is found below this glacial deposit in the upper part of the valley of the same general character as in the hills around it.

At the dam site and for a distance of three quarters of a mile upstream, where the bed rock drops off abruptly, the material underneath the glacial deposit consists of a thin layer of yellow clay overlying an extremely hard and compact blue clay and gravel, extending to a depth of more than 150 feet, as shown by borings.

The crest of the spillway dam is located at Elevation 390, Troy City datum, at which elevation the reservoir has an area of 1 685 acres. The maximum depth of water near the dam is 55 feet, and the average depth over the whole area, 22.4 feet. The total capacity of the reservoir is 12 310 000 000 gallons, 95 per cent. of which is available for use.

Of the area flooded, 250 acres were covered with woods and brush, the remainder being largely lands under cultivation. The trees and brush were all cut and removed from the area. The

farm buildings, of which there were seventeen sets, were entirely removed and the areas occupied by them carefully cleaned up; 22 000 cubic yards of muck and decaying vegetable matter were excavated and removed from the area flooded.

The question of stripping the soil from the entire area covered by the reservoir was carefully considered by the writer. The conclusion was finally reached that while stripping would be a very good thing, better and more far-reaching results could be obtained for about one half the cost by a reasonable sanitary treatment of the drainage area, and by installing a proper filtration plant.

Several highways crossed the reservoir site, and it was therefore necessary to construct about seven miles of new highways to replace those abandoned. The alignment of these roads has been made to conform in a large measure to the contour of the ground. The maximum grade allowed was 5 per cent. The subgrade was shaped so as to have a crown of 6 inches, over which was spread a gravel surfacing 9 inches in thickness at the crown and 6 inches at the shoulders, thus giving the finished surface a crown of 9 inches. The finished width of traveled way is 20 feet. The gravel surfacing was thoroughly rolled with a grooved roller and wet when found necessary to thoroughly compact it. Side gutters 2 feet in width at the bottom and 1 foot in depth extend through all excavations. A ditch was also constructed along the side hill above all excavations, with a berm of not less than 6 feet between it and the top of the slope. All embankments exposed to the wash of the reservoir are covered with riprap or stone paving. Substantial guard rails have been erected along all embankments 3 feet or more in height.

The culverts consist of 6-, 10-, 15-, and 24-inch vitrified clay pipe with concrete or cobblestone headwalls. These culverts have not been entirely satisfactory, especially in clay soil or where a small trickling stream flows all the time.

There are five bridges on the highways, with spans varying from 16 to 80 feet. The 16-foot span bridge was built with rolled I-beams. Three others were built with lattice girders, and floor systems of rolled I-beams. The fifth, an old bridge, was raised 4 feet and new abutments built under it. All abutments were built of 1 to 6 gravel concrete.

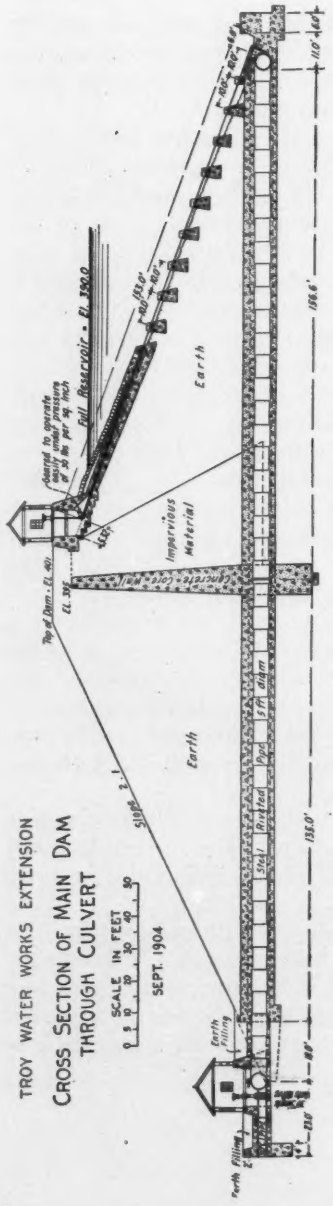


FIG. 2.

At the point selected for the dam the ravine is about 200 feet in width at the bottom and 500 feet at the top of the dam. An examination of this site had revealed the fact that it would be impracticable to reach bed-rock. Test pits dug along the proposed center line of the dam showed a depth of from 1 to 5 feet of loam and gravel, followed by a blue clay and gravel of unusual hardness and tenacity. This latter material is of great depth, as shown by the borings, and the formation was considered exceptionally good for an earth dam.

The general cross-section of the dam finally adopted, as shown in Fig. 2, has a top width of 24 feet, finished off as a highway; a back slope of 2.4 to 1; a front slope of 2 to 1; and a maximum height of about 70 feet. The back slope is paved to a point 15 feet below flow line and the remainder is covered with riprap.

The dam site was stripped of all loam and gravel down to the yellow clay. The area to be covered by the selected hard material was excavated down to and about 6 inches into the hard blue clay and gravel. There was also a cut-

off trench 4 feet in width and 2 feet in depth excavated along the toe of the up-stream slope, and another about midway between the toe and the selected hard material. The trench for the core wall was excavated to a depth of not less than 16 feet into the hard blue clay and gravel. At the westerly end, as the excavation was extended into the hill, a pocket of loose blue clay and gravel of a very porous nature was encountered, and it was found necessary to excavate to a depth of about 60 feet to procure a suitable foundation.

To provide for the flow of the stream during construction, a culvert $6 \times 6\frac{1}{2}$ feet, horseshoe-shaped, was built of concrete along the westerly side of the stream and the water turned into it by means of a canal and small cofferdam. It was the intention of the designer of the work to eventually close this culvert with concrete and gravel. With this in view two 36-inch sluice gates were placed at the upper end to control the flow through the culvert. These gates were of sufficient size to take the ordinary summer flow of the stream. Before the completion of the work, however, it was considered advisable to have a permanent opening through the dam at this culvert in order to unwater the reservoir should circumstances require it; a wise precaution in this particular case, as will appear later. This culvert is shown in Plate I, Fig. 2.

The plan followed for converting this culvert into a permanent opening was to build into and through it a 5-foot diameter steel riveted pipe $\frac{1}{2}$ inch in thickness. At the upper end of this pipe is a T carrying three sluice gates, each having a clear opening of $1\frac{1}{2} \times 4\frac{1}{2}$ feet. These gates were made narrow and long, so as to build them into and disturb the old work at the upper end of the culvert as little as possible. The gate stems were carried up the slope on bronze rollers, supported by concrete piers, to a gate-house located at the top of the dam. At the outlet end of the pipe is placed another T, carrying four 30-inch gate valves. This arrangement furnishes a means of regulating the flow through the pipe in case of accident to the sluice gates at the upper end, and of relieving the pressure upon them should it be necessary. A substantial brick gate-house is built over these gate valves.

The core wall of the dam is of concrete consisting of one part

Portland cement to five parts sand and gravel. The wall is 9 feet in thickness at the base and up to Elevation 340, from which point it batters uniformly on both sides to the top, at Elevation 395, where it is 3 feet in thickness. The concrete was deposited in 6-inch layers and thoroughly rammed. Above the surface of the ground the forms for the concrete were tied together with half inch rods. On the up-stream side a wooden washer in the shape of a truncated pyramid of four sides, about 2½ inches in height, was placed over the rod on the inside of the form. When the forms were removed the washers were taken out, the rods cut off at the bottom of the depression, and the space filled up with rich cement mortar.

The embankments on both sides of the core wall were carried up simultaneously with the wall, but the core wall was always kept at least one foot higher than the embankments, and usually much more than that. The embankments were always kept higher at the outside edges than at the center. The material for the embankments was brought from borrow pits in dump wagons and placed one load after another the whole length of the dam. After a line of loads had been completed, a road machine was used to scrape them down to a 4-inch layer. The layer was then watered and rolled thoroughly with a grooved roller weighing 1 000 pounds per linear foot. The teams were also kept from driving in one place as much as possible and thus aided in compacting the earth. The material from the borrow pits was not uniform in character, being at one place yellow clay and sand and at another almost wholly very fine sand or coarse gravel. As the loads came to the dam they were inspected and only the best material placed on the up-stream side.

The selected hard material for that part of the embankment next to the core wall, on the up-stream side, was to have been of the hard blue clay and gravel underlying the valley. As it was found impractical to reduce it to a sufficient degree of fineness to puddle satisfactorily, a fine blue clay was substituted. This material was deposited and compacted in much the same way as the other material, except that greater care was taken with it. After the road machine had leveled off the loads and a disk harrow had been run over the material until all lumps were broken up, it

was thoroughly soaked with water and rolled. Near the core wall the lumps were broken up with mattocks and the material thoroughly compacted with hand rammers.

The embankments were carried 6 feet higher than the core wall and 11 feet higher than the crest of the spillway dam. Along the top of the embankment, on the up-stream side, a concrete curb was built, upon which was erected an iron pipe guard rail, while along the down-stream side the iron guard rail was placed on concrete blocks.

The spillway dam is located in a depression in the hills about 1 000 feet southwesterly from the main dam. It is built of concrete of the general cross-section shown in Fig. 3. The maximum depth of the cut-off wall is 25 feet below the crest. Back of this dam an 18-inch cobble paving is laid for a distance of 14 feet, with a slope of 2 feet in that distance. Beyond the paving the earth is excavated on a descending grade of 1 per cent. until it intersects the original surface.

The crest of this dam is 300 feet in length, and at each end are retaining walls rising to a height of 10 feet above the crest, to protect the earth embankment necessary to complete the dam. For a distance of 75 feet from the dam there was originally laid a vitrified brick pavement on 6 inches of gravel concrete, with a cut-off wall at the lower end. The retaining walls at each end of the dam are extended along and terminate in a twist wall at the end of the paving. From the spillway dam a canal is built around the hill at the westerly end of the main dam and enters the creek about one-half mile below. At the dam it was 300 feet in width, but narrowed down to 40 feet in going the first 800 feet. The canal was made in part by excavation and in part by building embankments. The embankments are 12 feet in width at the top and thoroughly rolled and compacted. At a point about 1 000 feet from the spillway dam the canal makes a descent of about 20 feet. To overcome the abrading action of the water at this point, two flights of stone masonry steps with retaining walls of concrete on either side were built. The upper flight consists of 7 steps of 1 foot rise each, and of width varying from 1 to 3 feet. The lower flight consists of 13 steps of 1-foot rise each and of width varying from 1 to 4 feet. Between the two flights of steps, a distance of

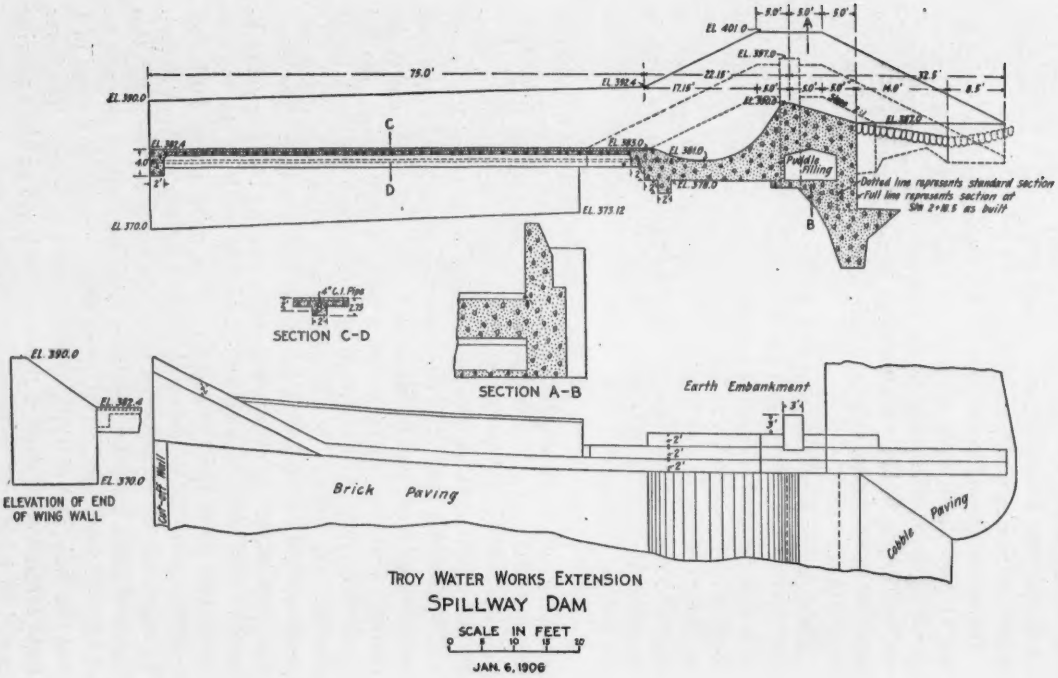

EL. 401.0
EL. 397.0
EL. 392.4
EL. 390.0
EL. 387.4
EL. 383.0
EL. 381.0
EL. 378.0
EL. 373.12
EL. 370.0
EL. 387.0
79.0'
17.15'
22.15'
32.5'
14.0'
8.5'
5.0'
4.0'
2'
C
D
B
Puddle filling
Dotted line represents standard section
Full line represents section at Sta 2+18.5 as built
6" C.I. Pipe
SECTION C-D
SECTION A-B
Earth Embankment
Brick Paving
Cut-off Wall
Cobble Paving
ELEVATION OF END OF WING WALL
TROY WATER WORKS EXTENSION
SPILLWAY DAM
SCALE IN FEET
0 5 10 15 20
JAN. 6, 1906

FIG. 3.

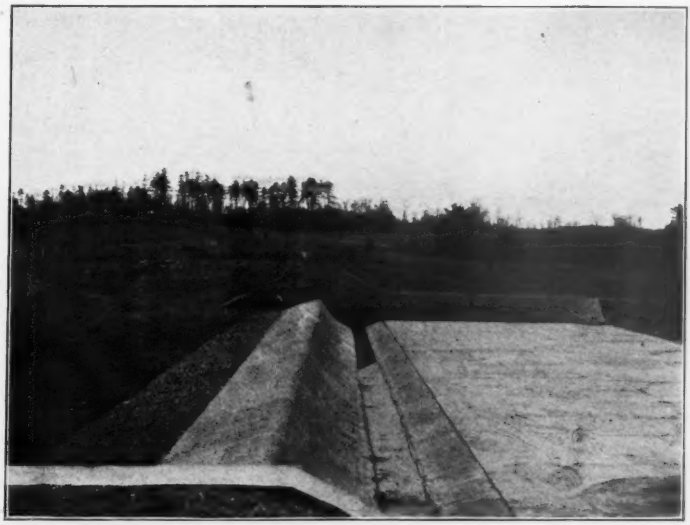


FIG. 1. Spillway Dam.

FIG. 2. Condition of Apron of Spillway Dam after the Flood of June 23, 1906.

134 feet, and for 50 feet above the upper and 50 feet below the lower steps, the bottom of the canal is paved with vitrified paving brick laid on 6 inches of gravel concrete. A view of this dam is shown in Plate II, Fig. 1.

On the afternoon of Saturday, June 23, 1906, a shower of unusual magnitude occurred on the drainage area, being especially severe in the southerly part along the Grafton Mountains. At this time the water in the reservoir had just reached the elevation of the crest of the spillway dam. The water in the reservoir had not begun to rise at 6 o'clock Saturday evening, but at 9 o'clock the next morning it had risen to a height of 14 inches above the crest of the spillway. As soon as the high stage of the water was learned, the gates of the " Permanent Opening " through the main dam were opened and the water drawn down, thus relieving the spillway of a large quantity of water, and undoubtedly preventing a great amount of damage. Measurements showed the flow into the reservoir between 6 o'clock at night and 9 o'clock the next morning to be at the rate of 2 200 cubic feet per second, equivalent to 32.7 cubic feet per second per square mile, while the maximum flow over the spillway was about 1 300 cubic feet per second. The effect of this rush of water through the spillway canal was very disastrous under the existing conditions. Before the water could be entirely diverted from the spillway, the cut-off wall and a considerable portion of the brick paving below the dam had been undermined and destroyed, the canal had been badly eroded, and the highway bridge abutments undermined, as shown in Plate II, Fig. 2.

The canal is being reconstructed and widened. The plans now being carried out contemplate the widening of the narrow part of the canal to twice its former width, and the introduction of more steps and rollways so as to eliminate the steep grades in the canal that previously existed.

The city supply is taken from the reservoir through a tunnel 5 900 feet in length, the entrance to which is located about 1¼ miles southwesterly from the main dam. The gate-house at the entrance to this tunnel contains two chambers, each having three 36-inch sluice gates arranged at different elevations, so that water can be drawn at 8 feet, 21.5 feet, and 35 feet from the surface.

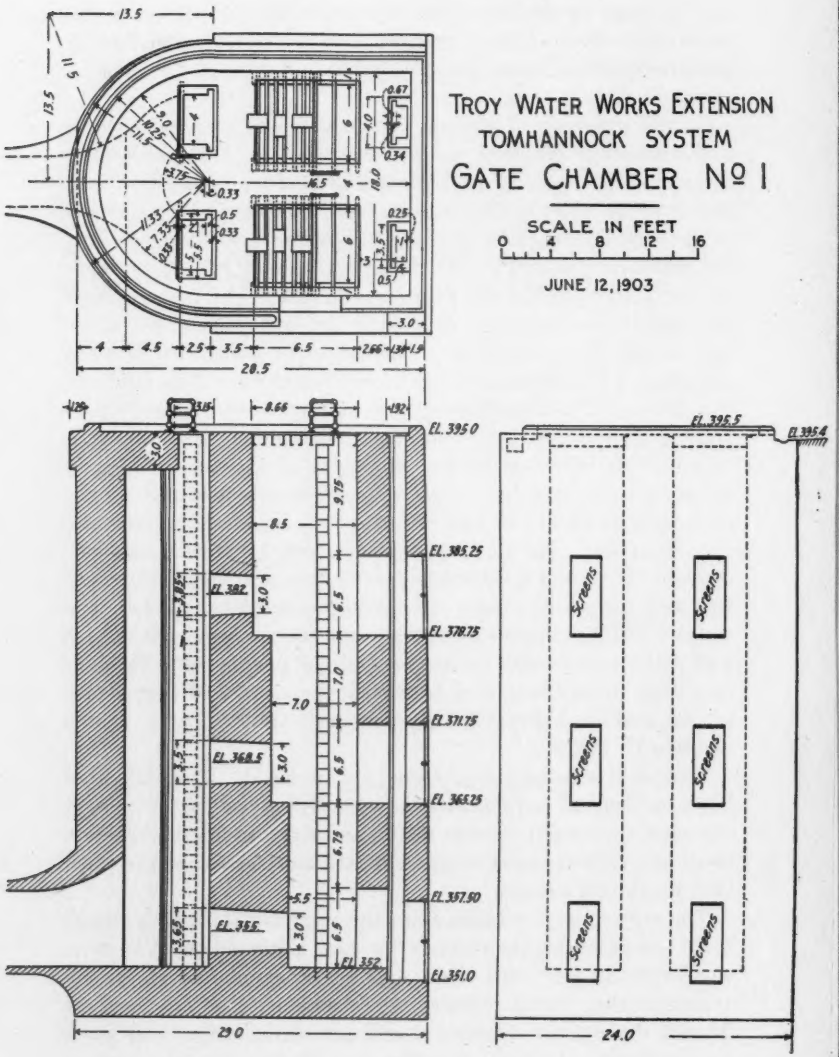
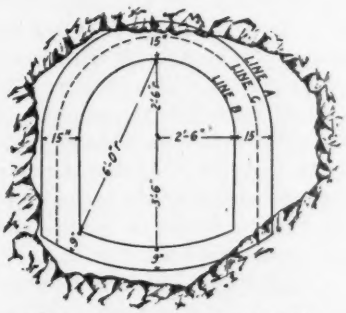
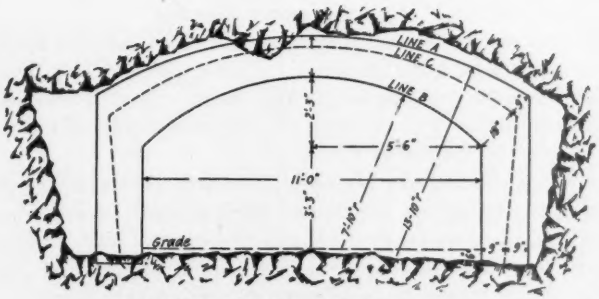

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
GATE CHAMBER Nº 1
SCALE IN FEET
0 4 8 12 16
JUNE 12, 1903
EL. 395.0
EL. 385.25
EL. 382
EL. 378.75
EL. 371.75
EL. 368.5
EL. 365.25
EL. 357.90
EL. 355
EL. 352
EL. 351.0
EL. 395.5
EL. 395.4
Screens
29.0
24.0

FIG. 4.

Provision is made for stop planks on each side of the gates to assist in making repairs. The openings into the gate chamber are guarded by heavy bronze screens. (See Fig. 4, and Plate III, Fig. 1.)



FROM STA. 5+90 TO STA. 66+55
ROCK SECTION TAKEN AT STA. 49+75



FROM STA. 2+0 TO STA. 5+90
ROCK SECTION TAKEN AT STA. 4+20

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
STANDARD SECTIONS FOR CONCRETE LINING
SCALE IN FEET
0 1 2 3 4 5
SEP. 12, 1903

FIG. 5.

The first 5 470 feet of the tunnel was originally intended to have a cross-section of about 4 × 6 feet, and be unlined, while the remaining 430 feet was to be about 6 × 11 feet to allow of laying two conduits through it. It was afterward decided to line the tunnel with concrete. The cross-section adopted for the small tunnel has a semi-circular arched roof and is 5 × 6 feet inside measurements, and for the large tunnel 5.5 × 11 feet inside measurements, with segmental roof. (Fig. 5.) At the junction of the large and small sections of the tunnel a gate chamber is built, containing the gates which control the flow into the conduits. Access is had to the large tunnel through a well 5 feet in diameter, built at the opposite end from the gate chamber. All the structures connected with the tunnel below the surface of the ground are of concrete of the same proportions and material as used in the dam. The gate-houses above the ground are built of brick.

The tunnel extends its entire length through what is known as Hudson River shale. Near each end it appears laminated and has occasional soft seams, but as the tunnel penetrates further into it the rock becomes harder and the laminations are not so distinct. The dip of this rock is very irregular.

Excavation was carried on through four shafts and the opening at the end toward the reservoir. Steam was used for drilling during the sinking of the shafts and the driving of a few feet of the tunnel each way from them, but the greater part of the work was done with compressed air.

Only one conduit has been laid, although provision has been made in the tunnel for the second when it shall be needed. It consists of about 6¾ miles of 33-inch riveted steel pipe, connnecting with the old 30-inch cast-iron force main at Twenty-first Street, in the former village of Lansingburgh. From this point to the lower Oakwood Reservoir the old force main was utilized. The conduit has a carrying capacity of from 15 000 000 to 18 000 000 gallons daily. Automatic air valves have been placed at all summits, and blow-offs at all low points. Manholes are provided every 500 or 600 feet in the steel conduit. It is also provided with seven gate valves placed at approximately equal intervals along the line. At five points these gate valves are placed at summits in the conduit line and, together with the air valves, are

enclosed in small brick gate-houses. At the other two points the gates are in the street and the gate chambers are entirely underground. Access is had to these gate chambers through manholes built on the side. (Fig. 6.)

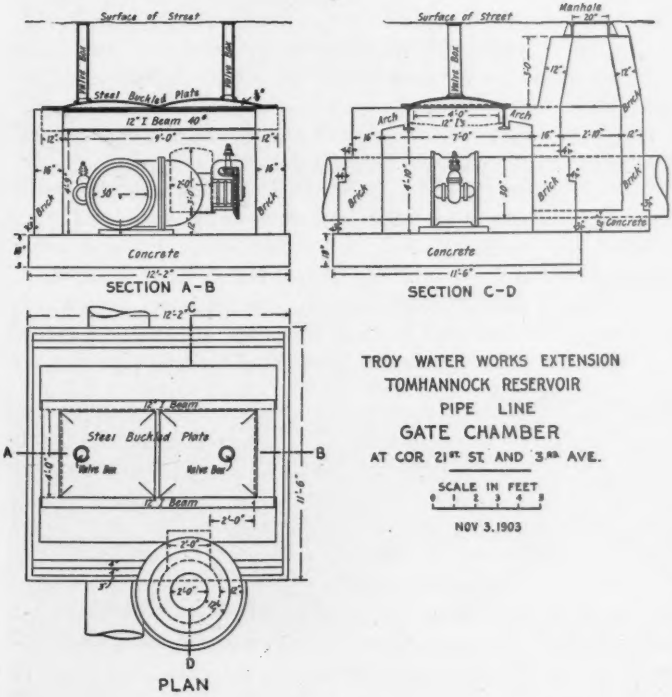


FIG. 6.

THE LANSINGBURGH SYSTEM.

The former village of Lansingburgh was annexed to the city of Troy in 1900. At that time Lansingburgh was supplied from three small reservoirs located just easterly of the village. It had also in the process of construction a masonry dam on the Deepkill and a 12-inch pipe line leading from it to the reservoir, to provide an additional supply. When the city of Troy came into possession of the work, Professor Raymond found that part of the new Deepkill dam rested upon rock foundation and part upon piles. After a careful examination of the location and conditions, he decided it would not be advisable to build the dam to its intended height, and consequently the upper 20 feet originally designed were never built.

The dam consists of a concrete core faced upon both front and back with coursed masonry. (Plate III, Fig. 2.)

What appeared to be a leakage under the dam was discovered near the center shortly after the work was completed. An attempt was made to check it by depositing clay and other materials above the dam, but this seemed to have little effect. While the quantity of water escaping was not large, a recent examination indicated some increase in volume, and that it was concentrated at a point a few feet to the right of the mud pipe near the center of the dam. The reservoir is of small capacity and only serves as a diverting reservoir.

The water-shed tributary to this system includes about 10 square miles of very hilly country lying adjacent to and westerly of the Tomhannock watershed.

QUALITY OF WATER.

The general quality of the water from all these sources is very good. During the month of January of this year, 1908, the Tomhannock water gave considerable trouble from algæ. The Quackenkill and Deepkill waters have been in use since 1902, and the Tomhannock since May of 1906. Prior to those dates most of the supply was pumped from the Hudson River into the low service reservoirs. The beneficial effect upon the health of the city of the introduction of the new supply is shown by the following table:

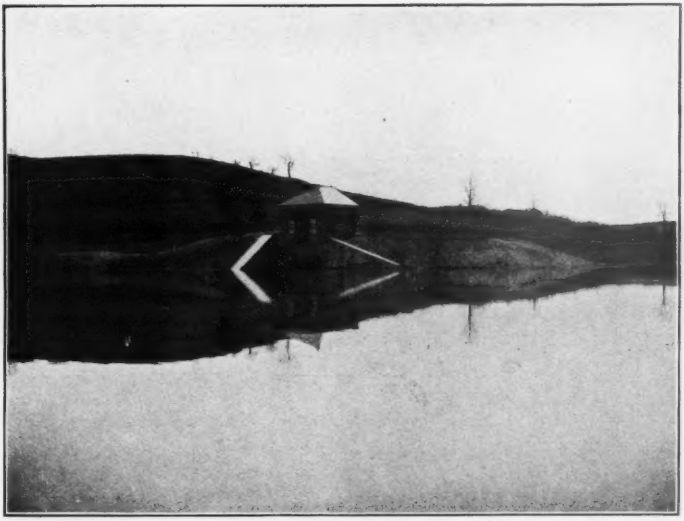


FIG. 1. Gate House at Entrance to Tunnel.

FIG. 2. Deepkill Dam and Reservoir, looking westerly.

Year.	Typhoid. Cases Reported.	Typhoid. Deaths.	Typhoid. Rate per 100 000.	Deaths. Cholera Infantum.	Deaths. Diarrhoea.	Deaths. Diseases of Digestive Organs.	Deaths. Children under 5 Years of Age.
1900	373	92	119.62	91	46	211	398
1901	176	43	55.91	56	45	178	370
1902	149	41	53.31	48	21	142	324
1903	110	23	29.91	19	10	97	315
1904	150	39	50.71	92	13	200	369
1905	160	39	50.17	70	14	184	394
1906*	91	27	35.11	24	12	113	317
1907	66	20	26.00	14	10	120	347

* Tomhannock water turned on May 21, 1906. Stopped pumping river water about May 1, 1906. Fifty cases and 15 deaths from typhoid fever reported before May 1, 1906. Average death-rate, 1901–1905, from typhoid fever, was 48.11 per 100 000. For 1906–1907 it was 30.56, or a reduction of 36½%.

COST.

The cost of construction of the different parts of the entire water works system to January 1, 1908, is as follows:

Original works and extension of Mains	$1 372 513.21
Original Lansingburgh Works	250 855.66
Deepkill System Lansingburgh Supply	150 507.67
Preliminary Investigations, Troy New Supply	25 545.18
Quackenkill System	265 916.75
Tomhannock System	1 337 138.12
Preliminary work on Filtration Plant	10 124.70
Total	$3 412 601.29

The plans for these new extensions were made under the direction of Prof. W. G. Raymond and the work was partially carried out by him. He severed his connection with the work in August, 1903, at which time the writer, who was the principal assistant engineer on the Tomhannock division, was appointed chief engineer.

POWER CAPACITY OF A RUNNING STREAM WITHOUT STORAGE.*

BY PROF. WM. G. RAYMOND, IOWA STATE UNIVERSITY, IOWA CITY, IA.

When a stream is to be developed for power, it is usual to examine such records of its flow as exist, and to take a few measurements of the minimum flow, if this is possible, as a basis on which to compute the probable minimum capacity and the probable ordinary capacity of the stream. The development is usually considered at some one point on the stream where a definite known head is available. When there are no records of the flow of the stream it is usual to examine its drainage area, compare it with that of some other stream for which there are flow records, compare also the rainfall on the two drainage areas, modify the percentage of rainfall running off from the area for which there are records, and determine the probable flow of the stream under consideration from its rainfall and these modified percentages.

While rainfall records are usually kept for each day, the published records are more commonly those of the calendar months, and this is true also of the flow records. In determining the percentages of flow on a given stream, it has been usually customary to average the flow for a number of years for each calendar month, and to compare this with the rainfall for the same calendar month for the same period. Among the streams of the eastern United States, it is found that as a general average about half of the rainfall runs off in the stream, the percentage varying in different years, according to the condition of the ground and according to the distribution of the rainfall. It is usual to say that the average conditions for power development will be shown by the average run-off or flow of the several calendar months of the year. And it is customary to determine what is called the ordinary flow,

* This paper, originally prepared for the Iowa Engineering Society, is now submitted as a discussion to the paper on "Stream Flow Data from a Water Power Standpoint," by Charles E. Chandler, published in the December, 1907, JOURNAL.

which is variously defined by different engineers, but which is understood usually to mean that flow for which it is wise to develop the stream for power.

If the calendar months are arranged in the order of their average yield, and the yields of these months are plotted to scale, a more or less irregular curve is the result, usually showing periods of regularity of from three to five months, broken by considerable differences of flow between these more regular periods. If, now, it is proposed to develop a stream for which such a plot has been made, and it is desired to determine for a given power development what portion of the year there will be sufficient water for the operation of the complete plant, and what portion of the year there will be shortage of water, and also the aggregate shortage for the year which must be made up by steam if a plant is to run continuously, the quantity of water necessary to supply the required power with the given head is determined and marked on the diagram. All those months which fall below the line of required yield will be short of power, while those months above will furnish full power, unless there be loss of head during extreme high water. Such a diagram, or such process, purports to show the conditions that will obtain as an average for the period of years that has been considered. The minimum flow at any one time indicates the maximum amount of power to be supplied by steam, and so, on such an investigation, a plant would be designed with a full water-wheel capacity and an auxiliary steam plant equal to supplying the maximum shortage of power. In estimating the cost of operating such a plant through a period of years, the average that has been mentioned would be considered.

It is a fairly well known fact that most plants that have been developed on such an investigation as this have proved disappointing in that the amount of water power available throughout the year has almost invariably fallen short of what was promised or expected, and consequently the auxiliary steam plant has been run at greater capacity and for longer periods than was estimated in the beginning. Indeed, some plants have been designed and built with the expectation that no auxiliary steam power would be required, while the first year's operation has developed the fact that considerable additional power would be needed.

The reason for this disappointment is not difficult to determine. If the records of flow are carefully examined, it will be found that there is no year of any considerable period of years in which there is not one or more months yielding considerably less water than the lowest average calendar month; thus, if by averaging the calendar months for a period of years, it is shown that July yields the smallest amount of water, it will be found to be true that in each year there will be one or more months, not always July,—sometimes January, sometimes September, sometimes May, sometimes some other month,—which will yield less than the average for July.

If there is no storage on the stream to equalize its flow, the more rational way of arranging the monthly records for power development is to average the lowest of the months of all the years, the next lowest, and so on; that is, the months of each year should be arranged in their order of flow, and the average of all the lowest months, next lowest, etc., taken. Such an arrangement of the months has been suggested by Professor Mead in his "Notes on Hydrology," which has just appeared. This is the first suggestion of this method of arrangement that the writer has seen, and this was not known until the notes for this paper were prepared.

The average of the months in their order of flow will show for the months of low flow a much less yield than the average by calendar months, and as the total flow must be the same, the averages of the high months are materially greater than the average of the high calendar months.

A diagram showing the two methods of averaging for the Sudbury drainage area covering a period of twenty-three years is shown in Fig. 1. The full line represents the calendar averages in order of volume discharged, the dotted line the averages of the months arranged in order of flow.

A similar diagram for the Perkiomen Creek, one of the streams that has been considered as a possible source of water supply for the city of Philadelphia, is shown in Fig. 2, the records extending over fifteen years.

Some time since, in the writer's practice, it became necessary to determine what portion of time a plant requiring about 170 cubic feet per second for its full power development would be without

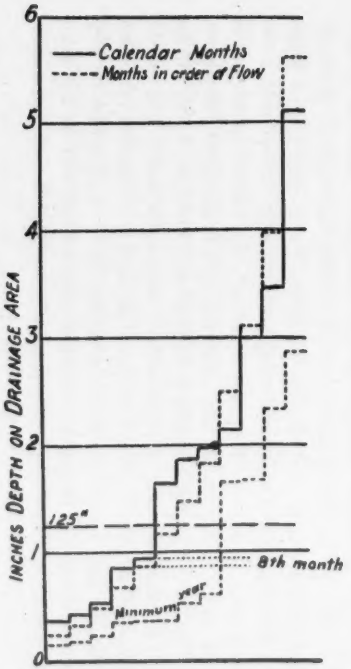


Fig. 1. Average monthly flow from the Sudbury Drainage Area for 23 years, in inches of depth on the area.

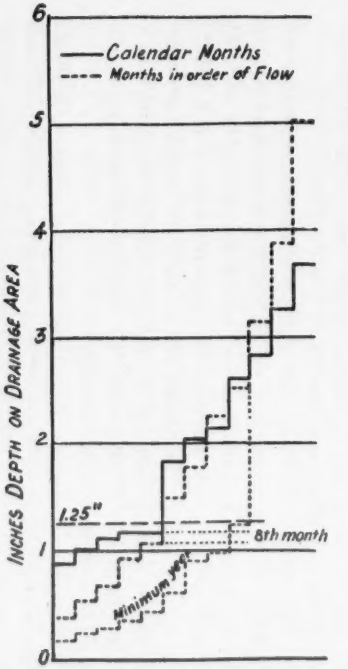


Fig. 2. Average monthly flow from the Perkiomen Drainage Area for 15 years, in inches of depth on the area

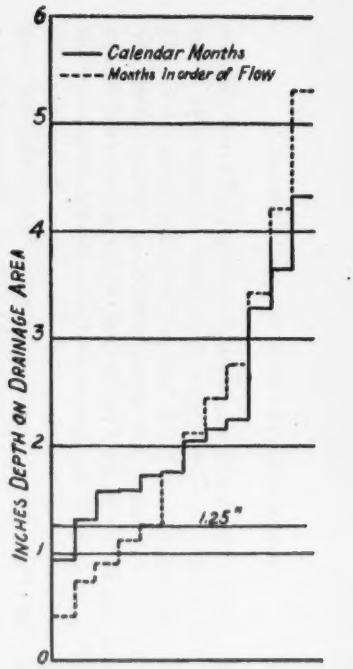


Fig. 3. Average monthly flow from the Perkiomen Drainage Area for 1887 '88, '89, '90, '91, and 93 in inches of depth on the area

full power. This plant was located on a stream not unlike the Perkiomen and of approximately the same drainage area. One hundred and seventy cubic feet per second is equivalent to 1¼ inches on the drainage area of the Perkiomen. Drawing the horizontal line on the diagram representing 1¼ inches, it is seen at once that by the average of calendar months there will be some shortage of power during five months of the year, and if the shortages for the several months are summed, it will be found that the total shortage is equivalent to full power for about three-quarters of a month. The dotted line showing the average of months in order of flow indicates that there will be a shortage for the same period, but that the aggregate shortage is nearly three times that shown by the average of calendar months.

If, now, instead of a developed plant, it be desired to consider the development of a new plant under the not uncommon rule of development, up to that flow that can as an average be counted on for eight months of the year, the diagram shows that it will be safer to develop by the dotted curve, since the eighth month by this record is lower than by the record of calendar months, and it is also plain that it will be best to compute the shortage by the record of months in order of flow.

The record by calendar months would show a proper development corresponding to a run-off of 1.17 inches, while the curves showing the months in order of flow indicate that the development should be for 1.09 inches, a not very great difference. But if the stream be developed for a flow of 1.17 inches, the calendar record indicates a shortage aggregating only fourteen days of full power, while the record arranged in order of flow indicates a shortage aggregating nearly two months of full power, or about four times the shortage shown by the calendar arrangement. Even with a development of only 1.09 inches of run-off, the months arranged in order of yield show a shortage aggregating 1.7 months of full power.

This, it will be understood, is an average condition, but it will be well to examine what may occur in a minimum year. The record of the lowest year in the 15 recorded, is shown on the diagram, and indicates that whether the development be for 1.17 inches or 1.09 inches, there will be eight months in which there will be less than full power. And if the development be for 1.17 inches, the aggre-

gate shortage will be equivalent to 4.6 months of full power. The record further shows that this may approximately occur for two or three years in succession. As this period may very likely accompany a period of business depression, it must be fully taken into account in advising the utilization of a given water-power.

The diagram for the Sudbury drainage area shows the same general condition, but the difference is less marked. If developed on a basis of the calendar month record, the shortage shown by the calendar month diagram aggregates 1.67 months of full power as against 2.2 months shown by the diagram of flow arranged in order of volume.

If the stream is developed on a basis of the lower curve, there will be a shortage aggregating two months of full power. As before, the minimum year shows a shortage extending over eight months; and if the stream be developed by the calendar record, this shortage will aggregate 5.2 months of full power; while, if developed by the record arranged by months in order of flow, the shortage will still aggregate nearly five months of full power.

It is seen from these considerations that the far more reliable method of arranging run-off records for determination of power when there is to be no large storage on a stream, is to arrange the monthly records in the order of flow rather than by calendar months. But even this is very far from the most desirable method. Particularly in the low months is the record of a whole month affected by the run-off of one or two days during or immediately following heavy storms. So that the monthly record never shows less than the power available in the stream, and practically always shows more power than can be used, since during the two or three days which bring up the total flow of a month the discharge is far in excess of that that can be used, and the greater portion of the water goes to waste.

The smallest unit of time which it is probably wise to consider is the day. Only a few daily records were available for the preparation of this paper. The best that were at hand were the records of six years of flow on the Perkiomen, the years being from 1887 to 1893, inclusive, excepting the year 1892, which was lacking. Judged by its monthly flow, the record of which was available, the year 1892 was perhaps the lowest of the seven years, while the

year 1899 was one of the two highest years observed in fifteen. The omission of the year 1892, therefore, from the record leaves the average daily flow for this period too great, but for the purpose of comparing monthly and daily records the omission is perhaps not serious.

Selecting these six years, and treating them as has been already done for the fifteen-year period of the Perkiomen, and considering for the time being only the power available for the particular plant assumed previously, namely, one requiring 170 cubic feet per second or 1¼ inches of run-off from the drainage area, the calendar month arrangement shows (Fig. 3) that there will be a shortage of power for one month only, aggregating seven days of full power, while the arrangement by months in order of flow shows that there will be a shortage during four months, aggregating about one month and thirteen days of full power, or nearly six times as much power to be supplied by steam as is indicated by the calendar month record.

But how is it when the daily record is examined? For this examination the daily flow of each year has been arranged in order of magnitude. The resulting record for the lowest year, the highest year, and the average for the six years is shown on Fig. 4. Considering again the particular plant already assumed, using 170 cubic feet per second, the diagram shows there will be a shortage extending over two hundred and eight days, or about 6.8 months instead of four months as by the monthly method, and that this shortage will aggregate about 3.2 months of full power, nearly thirteen times the amount of power to be supplied by the calendar month arrangement, and over twice that to be supplied as indicated by the monthly record arranged in order of flow.

Even this average does not tell the exact truth, because when the record of any day in any year exceeds 170 cubic feet per second all the flow above this volume tends to lift the average of the six years, but is itself unavailable for power; and to get at the exact truth, it is necessary to make an average in which the flow in every year for each day that has a larger value than 170 cubic feet per second, must be taken as only 170 cubic feet per second, until the flow of that year in which the low flow extends furthest reaches 170 cubic feet per second. Making such an average for these six

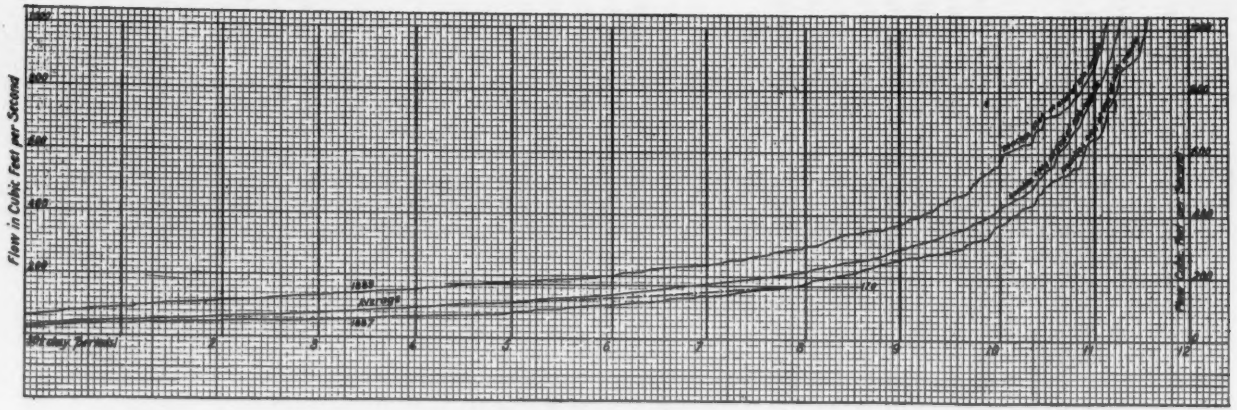

Flow in Cubic Feet per Second
1919
Average
1917
May Forecast

FIG. 4.

years, it is found that the shortage will extend over two hundred and thirty-seven days instead of two hundred and eight days, giving an aggregate of about one hundred days of full power to be supplied by steam.

The addition to the aggregate determined from the straight average is not large, but the cost of supplying this power is not in proportion to the amount of power supplied. If the steam plant were run constantly with not too large variations in power, the cost would perhaps be somewhat nearly proportional to the amount of power supplied, being determined largely by the quantity of fuel consumed. But where the amount of power to be supplied is very small, the labor item becomes relatively large, and the cost per horse-power hour becomes relatively greater than during those days when the steam plant is run more or less nearly up to its full capacity.

The general purpose of this paper has been to show that for streams on which there is little or no storage, the only proper way to estimate the power available for any development is to estimate it from the daily rather than the monthly flow; and to show the very considerable discrepancy that exists between the commoner method by monthly flows and the suggested method by daily flows.

FILTER OPERATIONS, INVESTIGATIONS FOR ADDITIONAL SUPPLY AND CONSTRUCTION OF NEW FILTER AT LAWRENCE, MASS.

BY MORRIS KNOWLES, CHIEF ENGINEER DEPARTMENT OF FILTRATION, PITTSBURG, PA.; M. F. COLLINS, SUPERINTENDENT OF WATER WORKS, LAWRENCE, MASS.; AND ARTHUR D. MARBLE, CITY ENGINEER, LAWRENCE, MASS.

[*Read February 12, 1908.*]

INTRODUCTION.

As is explained in the title of this paper, it is the intention, *first*, to consider the history of the operations of the old filter, which was started in September, 1893. Also, in connection with this, to tell about the changes in methods of operation and new items of construction or equipment for the old filter:

Second, to give a history of the agitation for obtaining a new supply, both by driven wells and by additional filter construction:

Third, to give a brief description of the filter and some of the items of cost which have entered into it.

HISTORY OF FILTER OPERATIONS.

In order that the history may be continuous, the method of consideration has been the same as in a paper presented before the American Society of Civil Engineers, June 5, 1901, by Morris Knowles and Charles Gilman Hyde (Trans. Am. Soc. C. E., Vol. XLVI, December, 1901). Furthermore, for the purpose of making the comparison more convenient, the numbers used to designate the present tables are the same as those given in that paper.

Population. The first table presented is called No. 1, giving the population of Lawrence, Mass., for the past seven years.

TABLE No. 1.

POPULATION OF LAWRENCE, MASS.

Date.	Enumeration by	Population.
1900	United States census.	62 559
1901	Estimated.	64 050
1902	"	65 580
1903	"	67 150
1904	"	68 750
1905	Massachusetts census.	70 050
1906	Estimated.	73 320
1907	Local census.	76 600

It is to be noticed by this table that the city has grown to a marked degree, an average of 3.2 per cent. per year. The increase is especially noticeable during the last two years, and is undoubtedly due to the completion of two large and important mill buildings in the city which has increased the number of operatives.

The need for additional water supply facilities, already somewhat evident, became markedly so as soon as it was known that these manufacturing concerns were to increase. It is an interesting study to notice how by strenuous methods, with the lack of means for supplying plenty of water, the use of this commodity per inhabitant was kept down to an unusual degree. It is quite probable that this will very soon increase with a greater amount of water available. The decrease is noticed in Table No. 4, and is graphically shown in Fig. 1, giving the use per inhabitant as ordinates with the per cent. of services metered as abscissas; the years being given for each point.

GENERAL DESCRIPTION.

The character of the water supply of the city of Lawrence, and of the Merrimac River, from which that supply is taken, is so well known that no extended description will be attempted at this time. Briefly stated, the watershed of the river has an area of 4 630 square miles and contains a population of over 500 000. Probably 60 per cent. of this population live in cities, the sewage from which is discharged in a crude state into the river. In 1901 it was estimated that in the driest times the proportion of sewage to the river water amounted to one gallon in every forty flowing past the city of Lawrence.

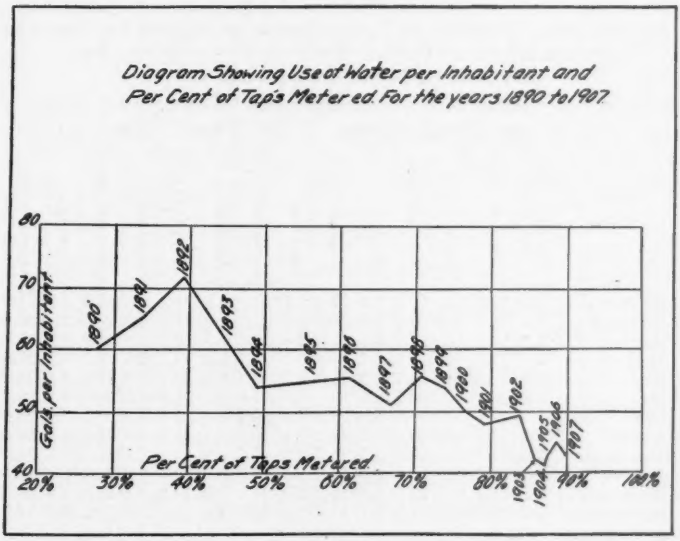


FIG. 1.

From the time of the completion of the original water works in November, 1875, to the fall of 1893, the city had been supplying this water, without purification, to its citizens.

In 1892 and 1893, after repeated outbreaks of typhoid fever, and a discussion lasting a year or more, the city took the advice of the State Board of Health and constructed a filter bed, 2½ acres in area, for the purification of its water supply. The details of this bed have been so completely covered in the paper before referred to, and so often considered in the reports of the State Board of Health, that a further description is needless.

In regard to the matters of operation, very little change has been made except in the building of the cross walls, which have divided the filter into three parts and made possible a scraping of one part while the other two are in use filtering water. There has been a change made in the method of handling the sand, throwing the dirty sand from the lower drive to the washer directly, without teaming, and this has saved some expense.

TABLE No. 4.

AVERAGE DAILY QUANTITY OF WATER PUMPED IN MILLION GALLONS, AND AVERAGE HOURS OF PUMPING PER DAY, AT LAWRENCE, MASS., FOR EACH MONTH, FROM 1901 TO 1907.

	1901.		1902.		1903.		1904.		1905.		1906.		1907.	
Month.	Quantity. Million Gals.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.
January	3.0	19.5	3.6	27.1	3.0	22.2	2.7	24.3	2.9	24.2	3.0	21.9	2.9	24.0
February ...	3.1	20.7	3.2	25.3	2.7	21.4	2.8	22.6	2.3	21.0	3.0	23.6	2.8	23.4
March.....	2.8	17.8	4.0	25.7	2.8	21.6	2.9	22.6	2.5	22.7	2.9	23.7	2.3	20.8
April.....	2.9	17.3	3.8	23.6	2.7	18.4	3.1	23.5	3.0	23.3	2.8	21.7	3.1	23.6
May.....	2.8	16.5	3.0	19.7	3.2	21.2	3.2	20.4	3.4	22.9	2.8	19.5	3.4	24.9
June	3.3	20.7	3.4	22.7	2.9	19.7	2.9	21.6	3.3	21.3	3.6	23.8	3.9	26.4
July.....	3.7	22.6	3.5	21.9	3.0	20.3	3.0	20.3	3.4	22.5	3.2	21.3	3.8	26.2
August	2.9	17.3	3.2	20.6	2.7	23.2	2.8	16.8	3.4	21.5	3.8	25.2	3.9	25.8
September..	3.6	21.5	3.1	20.3	2.7	25.7	2.8	17.7	3.4	19.1	3.7	25.6	3.6	24.1
October	3.1	20.6	3.2	20.9	3.0	19.2	2.6	17.3	3.0	19.7	4.2	26.5	2.9	19.4
November ..	3.0	21.1	3.1	23.6	2.5	18.5	2.4	21.1	2.9	19.6	3.4	24.6	3.2	26.3
December...	3.0	22.1	3.2	21.2	2.7	22.2	2.6	22.9	2.9	20.3	2.9	26.2	3.2	25.5
Average per day for year.....	3.1	19.1	3.4	22.5	2.8	21.2	2.8	20.7	3.0	21.6	3.3	23.1	3.3	24.2

Hours per day is sum of high and low service.

There have been times when the water in the river has not been high enough to flow by gravity to the filter, and at such times it was necessary to resort to pumping to supply water to the filter. Since January, 1900, an 8-inch centrifugal pump has been used to pump water from the filter surface in order to drain it more rapidly when preparing for cleaning. At no time has the filter been operated intermittently, with intention, since the data published in the American Society of Civil Engineers paper above referred to. The hours of pumping per day have also increased, so that the opportunities for air entering the sand have been somewhat lessened.

Use of Water. In Table No. 4 there are given, in comprehensive form, the average daily pumpage by months, including both services, and the average number of hours per day during which the

TABLE No. 5.

AVERAGE TEMPERATURES OF AIR AT LAWRENCE, MASS. ALSO THE MAXIMUM AND MINIMUM FOR EACH MONTH FROM 1901 TO 1907.

Month.	1901.			1902.			1903.			1904.			1905.			1906.			1907.		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
January	23.4	47	—2	23.2	54	2	24.8	48	—6	17.2	42	—23	20.2	47	—8	31.9	66	4	22.6	55	—12
February	20.3	46	2	26.0	48	0	28.0	60	—8	17.8	46	—13	18.0	44	—13	26.3	56	—5	17.1	49	—18
March	34.0	58	18	42.3	64	24	42.6	76	18	31.9	67	—1	33.0	67	4	29.0	54	4	34.3	72	—6
April	44.2	76	40	47.6	74	36	46.5	83	21	43.0	71	20	45.0	68	20	45.6	76	23	41.6	75	23
May	55.0	86	44	57.2	88	40	58.9	90	31	60.4	89	36	56.0	84	33	56.6	90	33	52.0	82	29
June	68.6	96	52	64.1	89	53	60.2	86	38	63.0	91	38	64.6	90	39	65.5	87	40	63.9	94	39
July	73.4	94	60	67.9	92	58	70.1	96	51	69.8	89	49	72.0	94	51	71.2	89	47	71.6	92	53
August	70.8	90	64	66.8	92	60	63.8	84	47	66.5	87	45	67.8	89	46	72.2	92	50	68.0	95	46
September	64.2	92	42	61.8	92	48	63.4	93	34	60.2	79	30	60.4	80	34	63.4	89	36	62.0	87	38
October	52.2	78	33	51.4	80	32	51.0	74	26	47.1	68	21	50.8	79	24	51.0	71	28	46.8	72	20
November	34.4	68	12	43.4	75	28	36.7	73	9	34.8	56	8	38.0	63	11	38.9	66	17	39.2	60	19
December	27.9	62	2	24.4	50	1	24.2	52	—14	20.7	46	—4	30.6	58	3	24.8	48	—4	32.4	62	13
Average	47.4			48.0			47.5			44.4			46.4			48.0			46.0		
Maximum		96			92			96			91			94			92			95	
Minimum			—2			0			—14			—23			—13			—5			—18

pumps were operated. As the high-service pump is only operated a few hours each day, it will be seen that in recent years the use of water during the winter months has necessitated almost constant pumping.

Temperatures. Table No. 5 contains the statistics of the temperature of the air at Lawrence, which are given for the purpose of showing the effect that this factor has upon the use of water. It will be particularly noticed that the warm winter of 1905–6, during the months of December, January, and February, aided quite a little in saving the city of Lawrence from the disgrace of pumping raw river water into the mains.

Quantity Filtered. There does not seem to be any marked difference in the quantities filtered between scrapings as compared with the earlier results, and this is probably due to the fact that there are many other factors which enter into a consideration of this problem; for it is thought that the under-drains still continue to clog and one would naturally expect lesser and lesser yields. The data obtainable upon this point are presented in Table No. 6.

TABLE No. 6.

LONGEST PERIODS BETWEEN COMPLETE SCRAPINGS OF THE LAWRENCE FILTER FOR THE SEVEN YEARS FROM 1901 TO 1907.

No.	Last Day of Complete Scraping.	First Day of Next Complete Scraping.	Length of Period in Days.	Total Quantity in Million Gallons between Scrapings.
1	March 22, 1901	April 17, 1901	27	80
2	April 20, 1901	May 28, 1901	39	121
3	Aug. 30, 1901	Sept. 25, 1901	27	103
4	Sept. 27, 1901	Oct. 28, 1901	32	99
5	Oct. 31, 1901	Nov. 25, 1901	26	83
6	March 13, 1902	April 1, 1902	20	90
7	April 2, 1902	May 1, 1902	29	120
8	May 2, 1902	June 17, 1902	44	155
9	June 20, 1902	July 10, 1902	21	80
10	July 13, 1902	Aug. 5, 1902	24	100
11	Dec. 4, 1902	Jan. 1, 1903	29	93
12	April 26, 1904	May 12, 1904	17	58
13	Nov. 27, 1904	Dec. 18, 1904	22	58
14	April 7, 1905	April 27, 1905	21	69
15	April 30, 1905	May 21, 1905	22	74
16	May 25, 1905	June 12, 1905	19	74
17	June 15, 1905	July 9, 1905	25	86
18	Dec. 6, 1905	Dec. 27, 1905,	22	64
19	April 28, 1906	May 21, 1906	24	72
20	March 28, 1907	April 21, 1907	25	78
21	May 11, 1907	May 30, 1907	20	74
22	Aug. 21, 1907	Sept. 23, 1907	34	138
23	Sept. 27, 1907	Oct. 21, 1907	25	87

Scraping. Regarding the records of scraping, which are presented in Tables Nos. 7 and 8, there is but little to be said; the average numbers seem to vary about as they did before, with an indication that the total amount of scraping removed is somewhat less than previously. It is possible that this is in part due to the lessened opportunity for scraping and a greater amount being removed each time. There is certainly a much better understanding of the necessity of regularity in scraping than previously existed, and this uniformity was shown in the later scrapings in the tables previously presented.

TABLE No. 7.

RECORDS OF SCRAPINGS OF THE LAWRENCE FILTER, ARRANGED BY BEDS FOR EACH YEAR, 1901–1907.

Bed.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	14	14	9	10	14	16	13
2	13	14	9	10	14	16	14
3	13	14	9	10	14	16	15
4	13	13	9	10	13	16	15
5	13	14	9	10	14	16	16
6	13	15	9	10	13	16	16
7	13	15	9	10	15	16	15
8	13	15	9	9	14	16	15
9	13	15	9	9	14	16	15
10	13	13	9	10	14	17	14
11	12	13	9	10	14	17	16
12	13	12	10	10	13	17	16
13	12	13	10	10	14	17	16
14	12	13	9	10	14	17	16
15	12	13	9	10	13	17	16
16	14	13	9	10	13	17	16
17	13	14	9	10	14	17	16
18	13	14	9	10	16	16	13
19	12	13	9	10	16	16	13
20	12	12	9	10	16	16	15
21	12	13	9	10	16	16	14
22	11	15	7	10	16	16	14
23	11	15	7	10	16	16	14
24	11	14	7	10	15	16	14
25	11	13	7	10	15	16	14
Total	312	342	219	247	360	408	371
Average	12	14	9	10	14	16	15

TABLE No. 8.

RECORD OF SCRAPINGS OF THE LAWRENCE FILTER, ARRANGED BY MONTHS, FOR THE YEARS 1901 TO 1907.

Months.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
January	25	15	22	20	23	42	33
February	20	22	16	29	24	25	23
March	31	58	25	34	46	25	45
April	25	25	34	25	50	50	25
May	25	25	21	25	25	16	42
June	25	25	8	14	25	25	33
July	28	25	13	11	21	33	25
August	27	36	5	0	16	42	42
September	25	27	25	17	25	33	25
October	35	50	0	8	25	42	25
November	19	25	34	48	47	42	28
December	27	25	16	16	33	33	25
Totals	312	358	219	247	360	408	371
Averages	26	30	18	21	30	34	31

TABLE No. 9.

DEPTH OF SAND IN INCHES REPLACED AT CROWN OF EACH BED OF THE LAWRENCE FILTER FOR YEARS 1901–1907.

Beds.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	10.5	8.8	10.7	4.2	9.5	8.8	3.8
2	13.9	11.5	11.1	4.3	9.2	9.3	6.5
3	15.6	12.0	11.4	4.0	10.4	10.0	8.0
4	15.0	9.8	11.9	5.7	10.7	9.3	7.5
5	14.3	9.7	10.0	6.3	10.5	8.9	7.3
6	14.4	7.3	11.8	5.9	10.3	8.8	8.3
7	14.0	10.5	9.5	6.3	7.2	9.0	6.0
8	13.0	10.0	9.5	6.0	6.9	8.8	8.8
9	10.5	9.8	10.2	6.7	6.8	8.5	5.0
10	9.0	6.5	9.8	2.8	7.0	7.8	11.5
11	8.4	4.0	10.9	3.0	7.1	8.3	12.8
12	10.1	4.0	11.0	3.2	6.7	10.5	9.0
13	10.9	4.0	11.5	6.8	6.5	10.8	8.8
14	8.5	4.0	12.7	7.0	7.5	11.0	9.5
15	9.0	4.0	12.0	4.7	7.3	10.8	7.5
16	9.2	4.0	12.3	4.5	7.7	9.0	9.0
17	11.8	4.0	11.7	4.0	8.5	8.5	9.5
18	12.5	4.0	12.5	5.1	5.5	10.3	7.2
19	8.8	4.0	13.8	4.9	5.9	10.3	7.0
20	4.5	4.0	14.9	5.4	6.2	11.0	9.8
21	7.2	4.0	14.5	5.7	6.0	10.8	8.8
22	6.8	4.0	15.2	6.3	5.9	11.0	11.2
23	7.3	4.0	15.1	7.8	5.5	11.1	12.0
24	8.0	4.0	14.8	6.4	5.0	10.0	9.2
25	8.4	4.0	11.7	4.9	5.2	10.5	8.5
Averages	10.4	6.0	12.0	5.3	7.4	9.7	8.0

Sanding. In the matter of resanding the filter, as shown in Table No. 9, there is not the same uniformity. We find that there has been a less total amount of new sand added each year. This has probably been due to the fact that, anticipating a new filter and some changes in the design of the old, it was not thought best to resand too large a quantity and have this to remove before going ahead with the new work.

The loss of head has not been regularly recorded in recent years and is not given here.

Draining. Table No. 12 gives a tabulation of the number of times the filter was drained, and although, as previously stated, there has been no intent to operate the filter intermittently, it gives an idea of the number of times it was possible for air to enter the pores of the sand.

COST OF ADDITIONAL CONSTRUCTION.

In addition to the cost items mentioned upon page 287 of the American Society of Civil Engineers' paper, previously mentioned, there have been additional items of construction carried on during recent years, *viz.*, the building of a new ice conveyor, new sand washer, and paving of driveway and slope. The most important, however, was the erection of the dividing walls, which were built in the year 1902. All of these items are given in Table No. 13, their total cost being $10 500, bringing the total cost of construction, not allowing for interest or depreciation, to $90 880. (See Plate VI. of Mr. Collins' paper.*)

TABLE No. 13.

ADDITIONAL CONSTRUCTION AT LAWRENCE FILTER FOR THE YEARS 1901–1907.
(Amounts given to nearest ten dollars.)

1901.	Widening roadway, paving, etc	$2 370
	New concrete work at slopes	500
1902.	Dividing walls, piping, etc	6 770
	New ice elevator	900
	Total	$10 540
Previous additions, 1894–1900		14 880
Original cost		65 460
	Total cost to end of 1907	$90 880

* "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288.

TABLE No. 12.

NUMBER OF TIMES WHEN THE LAWRENCE FILTER WAS DRAINED, 1901 TO 1907.

	1901.	1902.*			1903.			1904.			1905.			1906.			1907.	
		W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.
Total.....	72	27																	
		2	2	2	15	15	15	19	16	17	25	18	22	23	20	21	17	18	17
Average per month.....	6		2.4			1.25			1.4			1.8			1.75			1.4	

* Division walls not completed until October 29, 1902. Previous to this time, in 1902, filter was drained 27 times. Letters to designated parts of the filter are: W, west portion; M, middle portion; E, east portion.

TABLE No. 14.

ITEMIZED STATEMENT OF COST OF MAINTENANCE OF THE LAWRENCE FILTER FOR THE YEARS 1901–1907.

Items.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
Scraping.....	$1 570.00	$1 990.00	$1 130.00	$1 400.00	$1 810.00	$1 870.00	$1 740.00
Scraping and sanding.....	1 010.00	530.00	1 000.00	570.00	1 020.00	930.00	990.00
Conveying.....	850.00	1 180.00	730.00	850.00	1 070.00	980.00	1 250.00
Washing.....	970.00	340.00	1 220.00	460.00	470.00	960.00	850.00
Removing of snow and ice.....	2 900.00	3 670.00	2 740.00	4 400.00	3 780.00	2 620.00	3 250.00
General.....	570.00	1 130.00	980.00	1 000.00	1 630.00	2 500.00	3 460.00
Total.....	$7 870.00	$8 840.00	$7 800.00	$8 680.00	$9 780.00	$9 860.00	$11 540.00
Per million gallons.....	6.94	7.14	7.56	8.41	8.92	8.22	9.67
Total minus snow and ice.....	4 970.00	5 170.00	5 060.00	4 280.00	6 000.00	7 230.00	8 290.00
Per million gallons.....	4.38	4.18	4.91	4.15	5.47	6.03	6.95
Special work and repairs.....	740.00	1 090.00		1 550.00	1 160.00		
Total pumpage for year in million gallons,	1 134	1 238	1 031	1 031	1 096	1 203	1 193

COST OF OPERATION.

General. The costs of operation and maintenance of the Lawrence filter were among the first to be thoroughly analyzed and published. Although the later figures exhibited but few differences (except perhaps there is a general downward tendency until the last two years), it has been thought advisable to present all of these factors, beginning with the year 1901, in order to bring these items to date. The heavier cost of operations per million gallons of the last two years is to be explained by the additional draft upon the filter capacity.

The present figures have not been looked up with the detail care employed in making up Table No. 14, on page 288 of the American Society of Civil Engineers' paper; but, as the methods of accounting were quite well established by the year 1900, it is believed that the figures now presented and taken directly from the reports of the Water Board are reliable and useful for all of these purposes of comparison. It will be noticed that figures have been presented to the nearest ten dollars.

Scraping Costs. The method of hand scraping is now so well understood that we will not attempt to give, in detail, a description of this, but, for the purpose of comparison there is presented in Table No. 15 a statement of the bed scrapings per year, together with the cost per bed and the cost per million gallons of water filtered. It is gratifying to notice that recently there has been a tendency toward a lower cost per bed, and the only reason why this has not been lower per million is undoubtedly the general lessened yield per unit between scrapings. (See Plate I, Fig. 1, of Mr. Collins' earlier paper.)

TABLE No. 15.

STATEMENT OF THE TOTAL NUMBER OF BEDS SCRAPED PER YEAR, TOGETHER WITH THE COST PER BED PER SCRAPING AND PER MILLION GALLONS FILTERED AT THE LAWRENCE FILTER, FOR THE YEARS 1901–1907.

Years.	Number of Bed Scrapings.	Cost of Scraping.	Cost per Bed for Scraping.	Cost per Million Gallons of Water Filtered.
1901.....	312	$1 570	$5.03	$1.38
1902.....	342	1 990	5.82	1.61
1903.....	219	1 130	5.16	1.10
1904.....	247	1 400	5.67	1.36
1905.....	360	1 810	5.03	1.65
1906.....	408	1 870	4.60	1.56
1907.....	371	1 740	4.68	1.46
Average	323	1 644	5.14	1.44

Washing Costs. As was previously mentioned, there has been but little change in this work except to add an additional washer in order to save some of the cost of conveying. Also, it has been arranged to throw sand from the driveway to the washer itself. Both of these have lessened to some extent the cost per cubic yard, and it is a pleasure to record that there is a general downward tendency in this factor. The details of this classification of accounts are given in Table No. 16. (See Plate I, Fig. 1; and also Plate I, Fig. 2, of Mr. Collins' earlier paper.)

TABLE No. 16.

DETAIL COSTS OF SAND WASHING OPERATIONS AT LAWRENCE FILTER FOR THE YEARS 1901 TO 1907.

Year.	Cost of Operations.			Cubic Yards Washed.	Cost per Cubic Yard.
	Labor.	Bills.	Total.		
1901.....	$870	$100	$970	2 024	$0.48
1902.....	340		340	885	.38
1903.....	1 170	50	1 220	3 046	.40
1904.....	440	20	460	1 170	.39
1905.....	470		470	1 500	.31
1906.....	670	290	960	2 877	.33
1907.....	850		850	2 192	.39

Snow and Ice Costs. There is but little need to comment upon these items of cost, which are given in Table No. 14; the method remains the same and the expense is fully as great as ever, much in excess of the interest on a sum of money needed to cover the present filter, and a yearly tax of from $2.50 to $4.00 per million gallons. This excessive expense for the three winter months of the year is an exorbitant one, which should not be endured any longer than is absolutely necessary. (See Plate II of Mr. Collins' earlier paper.)

RESULTS OF FILTRATION.

Chemical. In the matter of chemical results there is but little change from the previous determinations. It appears that the color in the effluent is somewhat higher than during the previous six years, as is also chlorine, in both river water and effluent.

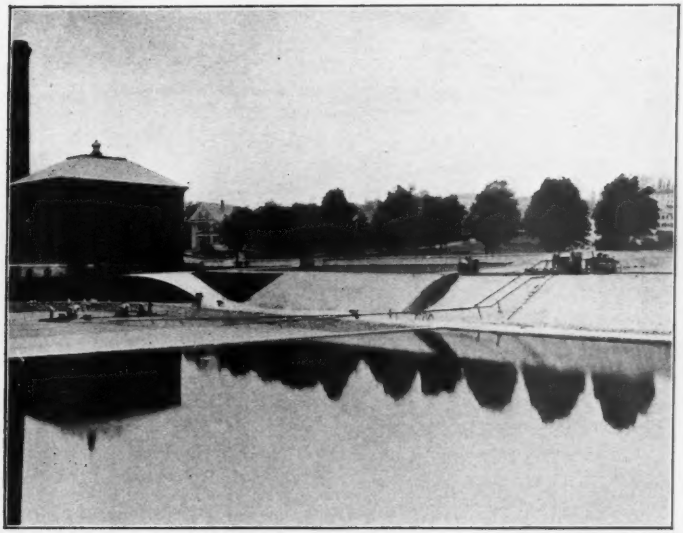


FIG. 1. Transporting Scraped Sand from Filter to Washer.

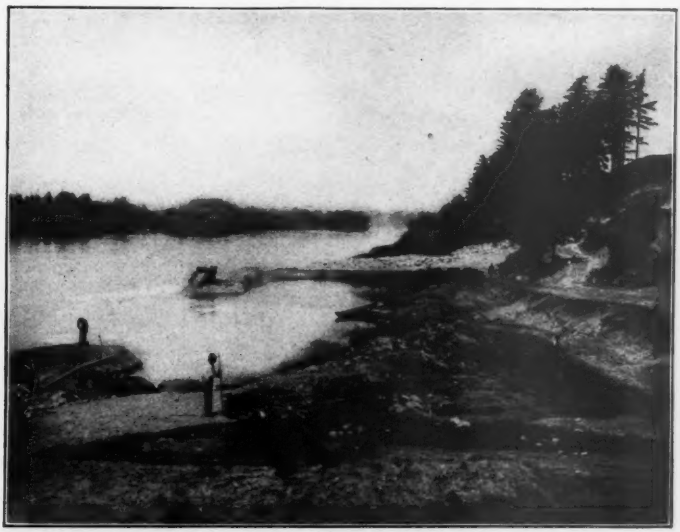


FIG. 2. Site of Filter, showing Work on Embankment, Jan. 28, 1906.

TABLE No. 17.

RESULTS OF CHEMICAL ANALYSES OF APPLIED MERRIMAC RIVER WATER AND EFFLUENT FROM LAWRENCE FILTER FOR THE YEARS 1901 TO 1907 (PARTS PER MILLION).

Year.	Yearly Rainfall in Inches.	Color.			Ammonia.						Chlorine.		
					Free.			Albuminoid.					
		River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	45.58	4.1	3.5	15	0.109	0.078	28	0.190	0.077	59	2.1	2.1	0
1901	45.53	5.1	4.6	10	0.111	0.103	7	0.226	0.102	52	2.5	2.5	0
1902	46.88	4.7	4.9	—4	0.081	0.091	—12	0.200	0.095	52	2.4	2.6	—18
1903	38.09	4.1	4.2	—3	0.09	0.098	—9	0.194	0.082	58	2.8	2.9	—4
1904	38.83	3.9	4.4	—13	0.126	0.125	1	0.216	0.092	57	3.2	3.3	—3
1905	35.32	4.1	4.7	—15	0.133	0.122	8	0.240	0.109	55	3.3	3.6	—9
1906	39.71	3.8	4.0	—5	0.128	0.105	7	0.211	0.089	56	3.5	3.5	—6
1907	37.25	3.9	3.9	0.0	0.146			0.237			3.2	3.3	—3
Average, 7 years ..	40.23	4.2	4.4	—4	0.116	*0.107	*0.3	0.218	*0.095	*55	3.0	3.1	—6
Average 6 previous years.....	38.85	4.7	3.8	11.6	0.089	0.092	—3.4	0.199	0.094	52.8	2.2	2.4	—9

(*Continued on following page.*)

TABLE No. 17 — *Continued.*

Year.	Hardness.			Nitrogen.						Oxygen Consumed.		
				Nitrites.			Nitrates.					
	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	12	16	—33	0.002	0.001	50	0.11	0.38	—260	4.3	2.4	44.2
1901	12	17	—42	0.002	0.001	50	0.15	0.40	—167	5.7	3.6	36.8
1902	12	14	—17	0.001	0.000	100	0.13	0.28	—115	5.4	3.8	29.7
1903	14	20	—43	0.002	0.001	50	0.13	0.32	—146	4.8	3.2	33.3
1904	17	21	—24	0.003	0.000	100	0.16	0.40	—150	5.4	3.7	31.5
1905	13	18	—38	0.003	0.001	67	0.16	0.38	—143	6.2	4.2	32.3
1906	11	14	—27	0.003	0.001	67	0.14	0.34	—127	5.8	3.6	38.0
1907	11	17	—55	0.003			0.14			6.3		
Average, 7 years	13	17	—35	0.002	*0.0007	*72	0.14	*0.35	*—141	5.7	*3.7	*29
Average 6 previous years	14	21	—50	0.002	0.001	50	0.14	0.40	—190	4.2	2.8	33

* Average for six years, figures for 1907 not obtainable at this date.

The same may also be said in regard to the nitrogen determinations, except the nitrates. In fact, there seems to be a gradual increase in the organic impurities in the river water, and this is also seen in the bacterial determinations. Table No. 17 gives the general chemical determinations, in the form of averages for each year, together with the percentage removed for each constituent and the averages for whole seven-year period, compared with average of the previous six years.

Bacterial. It appears there has been an increase of the bacteria contained in the river in the last seven years, but it is gratifying to note that there is no increase in the numbers found in the filtered water. In fact, it may be asserted with safety that, in general, numbers are lower than ever, with an accompanying greater degree of purification.

There is, however, one notable fact, and that is that there does not seem to be a further reduction of bacteria in the passage of the water through the pipe system of the town, and the tap at City Hall very frequently shows bacteria no lower, and sometimes a few higher, than in the effluent from the filter.

A truer indication, however, of the work of the filter is shown by the coli determinations, and it is gratifying to note that the numbers of times that these organisms were found in one cubic centimeter of the filtered water is low.

DEATHS FROM TYPHOID FEVER AND GENERAL DISEASES.

By many the true benefit of the filter is considered to be best represented by the number of cases of and deaths from typhoid fever, and by the total death-rate of the community. There are some other factors in Lawrence, however, which are likely to produce typhoid fever, among which may be mentioned the polluted canal water supply; also the cases by importation and contact, and secondary infection from these. These causes are not, however, anywhere near as strong in Lawrence as in some communities, but we are reminded by the recent investigations in Washington, D. C., not to place too much reliance on the typhoid fever death-rate.

In order that we may have these figures at hand, there are given in Table No. 21, the number of cases and deaths from typhoid fever

TABLE No. 18.

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent.	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1900.							
January	12 800	110	99.1	83	89	41	15
February	12 100	73	99.4	52	57	10	0
March	5 000	36	99.3	50	316	8	0
April	3 300	27	99.2	28	43	0	0
May	3 200	70	97.8	23	50	40	0
June	1 250	68	94.6	43	184	17	0
July	3 900	35	99.1	39	59	0	0
August	7 700	17	99.8	12	101	20	0
September	19 200	18	99.9	27	179	14	0
October	15 500	72	99.5	50	34	0	0
November	16 800	58	99.7	60	127	12	0
December	5 600	64	98.9	40	108	37	12.5
Average	8 970	54	99.4	43	87	17	2.3
1901.							
January	5 600	61	98.9	34	92	11.1	37.03
February	2 500	24	99.0	32	82	13.04	0.0
March	8 900	50	99.4	26	69	17.64	0.0
April	1 400	15	99.0	17	34	0.0	0.0
May	1 400	8	99.4	9	20	0.0	0.0
June	3 000	58	98.0	25	22	25.0	0.0
July	1 760	11	99.4	12	11	0.0	0.0

August	1 580	18	98.9	14	7	0.0	0.0
September	1 760	15	99.1	9	9	0.0	0.0
October	1 900	22	98.8	11	10	0.0	0.0
November	1 300	7	99.5	6	5	0.0	0.0
December	5 100	22	99.6	26	8	0.0	0.0
Average	3 017	26	99.1	18	10.2	10.5	3.1
1902.							
January	7 300	47	99.4	58	21	4	0
February	7 400	44	99.4	51	45	4	0
March	4 500	61	98.6	64	20	6	0
April	4 200	75	98.2	66	16	0	0
May	3 300	30	99.1	26	28	0	0
June	2 700	32	98.8	40	55	0	0
July	3 700	35	99.9	57	161	0	0
August	20 900	324	98.4	112	219	14	0
September	15 300	23	99.8	66	104	0	0
October	10 000	105	98.9	125	53	0	0
November	4 300	25	99 3	103	83	0	0
December	7 000	109	98.4	96	72	8	8
Average	10 300	76	99.3	72	73	4	1
1903.							
January	12 500	58	99.5	71	32	0	0
February	7 000	33	99.5	75	23	4	0
March	4 100	20	99.5	38	40	8	4
April	2 200	12	99.5	19	24	8	8
May	4 100	18	99.6	24	58	0	0
June	18 200	14	99.9	45	141	0	0
July	3 800	18	99.5	27	68	25	0
August	4 000	17	99.6	50	66	20	0
September	38 400	20	99.9	41	141	0	0
October	40 300	29	99.9	85	178	0	0
November	5 300	32	99.4	33	70	88	0
December	14 500	110	99.2	85	95	4	4
Average	12 900	32	99.7	49	78	4.2	1.7

TABLE No. 18 — *Continued.*

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent.	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1904.							
January	10 100	70	99.3	55	62	4	0
February	7 200	55	99.2	36	51	12.5	8.3
March	4 000	33	99.2	46	23	0	0
April	2 700	20	99.3	57	12	0	0
May	3 100	16	99.5	24	53	0	0
June	5 600	22	99.6	44	70	0	0
July	8 000	11	99.9	35	125	25	25
August	3 500	14	99.6	135	34	40	0
September	19 400	16	99.9	45	129	0	0
October	5 600	26	99.5	60	93	0	0
November	15 600	90	99.4	43	110	10.5	10.5
December	17 900	75	99.6	65	115	4	0
Average	8 600	37	99.6	55	73	8	3.6
1905.							
January	14 200	110	99.2	70	101	20	0
February	14 800	55	99.6	33	125	0	0
March	10 300	55	99.5	55	98	0	0
April	3 600	170	95.3	60	38	8.7	4.3
May	1 900	12	99.4	34	26	0	0
June	9 600	9	99.9	23	60	0	0
July	3 900	55	98.6	75	57	0	0

August	19 500	37	99.8	51	272	33.3	17.6
September	13 500	44	99.7	53	189	10	0
October	39 800	110	99.7	65	169	0	0
November	8 700	70	99.2	70	160	0	37.5
December	11 500	24	99.5	46	122	0	0
Average	12 600	63	99.5	53	155	6	4.1
1906.							
January	8 600	52	99.4	55	105	7.4	7.4
February	6 400	38	99.4	23	80	0.0	0.0
March	5 400	22	99.6	26	57	3.7	0.0
April	3 200	19	99.4	26	31	4.5	0.0
May	1 600	16	99.4	26	51	0.0	0.0
June	1 000	6	99.4	60	59	25.0	0.0
July	6 200	18	99.7	70	143	0.0	0.0
August	4 100	13	99.7	35	1 160	0 0	25.0
September	2 600	11	99.6	60	61	0.0	0.0
October	5 200	12	99.8	110	85	0 0	20.0
November	1 900	11	99.4	22	44	0 0	0.0
December	2 900	20	99.3	16	153	0.0	0.0
Average	4 092	20	99.6	36	165	3.4	4.4
1907.							
January	3 900	33	99.2	45	101	9.1	0.0
February	3 000	18	99.4	20	54	0.0	0.0
March	3 200	19	99.4	39	58	3.4	0.0
April	2 200	14	99.4	19	25	0.0	0.0
May	700	9	98.7	12	42	0.0	0.0
June	950	10	98.9	8	69	0.0	0.0
July	2 600	20	99.2	48	62	20.0	0.0
August	3 000	29	99.0	19	168	0.0	0.0
September	5 700	22	99.6	38	87	25.0	0.0
October	1 400	10	99.3	16	105	0.0	0.0
November	3 300	22	99.3	54	140	4.4	0.0
December	3 400	26	99.2	23	100	3.3	0.0
Average	2 800	19	99.3	28	84	5.5	0.0

in the city of Lawrence, together with the rate per 10 000 and percentage of cases resulting in death; the total death rate in the city of Lawrence; the typhoid fever and total death-rates in the state of Massachusetts are also given as far as obtainable. The averages of the same data by years given in the former paper, for the six years prior to construction and the six years following construction, are shown for comparison with the average of the last seven years. The last figure shows remarkable uniformity, except for two years, 1903 and 1907,* the death-rate being kept well down, and it is indeed a gratifying result. It is also interesting to note the reduction in whole state, as well as the reduction in general death-rate in both state and city.

TABLE No. 21.

REPORTED CASES OF TYPHOID FEVER AND THE DEATHS RESULTING THEREFROM FOR THE YEARS 1901 TO 1907; ALSO THE DEATHS FROM ALL DISEASES AND SAME FACTS FOR THE STATE OF MASSACHUSETTS.

Year.	Number of Cases.		Number of Deaths.		Percentage Resulting in Death.	All Diseases, Death-Rate per 10 000, Lawrence.	Typhoid Death-Rate, Mass.	All Diseases, Death-Rate per 10 000, Mass.
	Total Reported.	Per 10 000 Population.	Total Reported.	Per 10 000 Population.				
1901	100	15	12	1.8	12	170.8	2.0	168.6
1902	102	15	11	1.6	11	177.3	1.9	162.1
1903	149	21	20	2.9	13	178.4	1.8	161.3
1904	61	9	10	1.4	16	165.9	1.6	154.7
1905	98	14	15	2.1	15	195.9	1.9	167.7
1906	105	14	13	1.7	12	182.8	1.6	166.1
1907	129	17	21	2.7	16	188.9	...	.....
Average	106	15	15	2.0	14	180.0	...	.....
†Average 6 years previous	188	43	53	12.0	28	.....	4.0	198.3
‡Average 6 years after	84	15	14	2.6	18	.....	2.6	183.3
Per cent. reduction	55	65	72	78	35	.....	...	.....

† Previous to construction of filter.
‡ After construction of filter.

STUDIES FOR ADDITIONAL SUPPLY.

The successive moves made by the Water Board and the city councils, before an appropriation was granted for construction of

* See discussion by M. F. Collins.

the new filter, form an interesting record of the ways of municipal activities. For some years the officials of the Water Department had been on the anxious seat, due to the lack of filter capacity, and many times the reservoir has been almost drained in the winter time.

In looking back over the history it seems almost incredible that this critical state of affairs should not have been recognized by every one and that each willing shoulder should not have been put to the wheel in making for progress and in obtaining something which could be accomplished within a reasonable time rather than to experiment upon ideas or conjecture.

1902 Agitation. The annual report of the Water Board for 1901 was the first to call attention to the imperative demand for additional filter capacity. Upon July 2, 1902, a joint meeting of the city councils was held to consider the need of the new filter, which meeting was addressed by Hiram F. Mills, civil engineer, member of the State Board of Health. The suggestions then made were that the old filter be covered and that a new one be located to the west of the old. It is interesting to note that this period is just about ten years after the first appropriation for the old filter. The meeting did not result in anything tangible. Councils inspected the old filter upon July 9 and, as the suggestions did not seem to be heeded, Mr. Mills thought advisable upon July 10 to transmit a letter of warning.

On July 11, 1902, the Water Board voted to construct the dividing walls which had been recommended by Mr. M. F. Collins, then "care-taker of the filter," in the annual report for 1900, and again advocated during this year. It was decided not feasible to cover the old filter at this time, but it was also voted to place meters on all services. On the 11th of the month, the city council voted $5 000 for the walls, and on the 25th, the contract was awarded to Joseph Wagenbach & Son for $3 322.78. The total cost of the work complete, including that done by the department, was $6 767.60.*

On August 7, the State Board of Health addressed a letter to the mayor and city councils advising that more complete steps

* See paper on "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288, for description and illustrations.

should be taken, as the walls would be of insignificant advantage, and other means of increasing the supply were urgently needed. The work of building walls was completed, so as to use the beds in sections on October 8, 1902, and advantages in the operation resulted, with less anxiety in the winter season.

1903 Agitation. The question of additional filter area was again recognized and came to the front in the first of the year 1903. The Water Board once more called attention to the condition and said that something should be done at once. Early in March it was arranged to have plans and specifications prepared for the new filter, and on March 14 surveys were begun by the city engineer for the purpose of securing the necessary information and data upon which to plan this work. During the latter part of the month a request was made of the city councils for an appropriation of $60 000. Notwithstanding all of this agitation and discussion, however, and the recommendations of leading citizens as to the necessity, the city councils withheld their approval, on the grounds of insufficient funds.

1904 Agitation. During the winter of 1903–4 conditions became so critical, the reservoir was so very low, and the accumulation of ice upon the filter so great that the yield grew less than ever. The State Board of Health, on February 17, warned the Water Board that dire results would follow if steps were not taken to husband the supply and curtail all possible waste. It was recommended, if stringent restrictions failed to give relief, that the Board should ascertain if water could not be obtained from either of the surrounding towns. Conferences were held for this purpose, but no action resulted thereform. Thereupon, the president and superintendent of the Water Board appeared again before councils, with a request that money be furnished to provide for building a filter according to the plans which had already been approved by the State Board of Health. Restrictive measures were helpful, as is shown by the lessened use of water.

Shortly after this, communications were received from two filtration companies, advocating certain special types of filters at lesser cost. There was considerable delay in considering the various plans and the impossibility of securing a new filter before winter was realized.

The driven-well proposition was first suggested about this time; a communication was received, April 21, 1904, offering to supply 2 000 000 gallons daily from wells to be driven on the south side of the river, nearly opposite the pumping station; however, nothing was done. The city government next endeavored, through the Water Board, to obtain water from adjacent towns, which request was made in the month of September, 1904. The result was a refusal of each town, on the ground that such action would be illegal.

1905 Agitation. The same condition continued during the winter of 1904–5, barely enough water being filtered to supply the daily need. There was no reserve in cases of emergency, but fortunately no extraordinary drain taxed the filter. Early in January of this year the joint standing committee on water works of the city council, together with the Water Board, were constituted a committee to determine whether a suitable supply could be obtained by driven wells. These investigations continued in many places for some months and lasted into the fall of the year. It is surprising, notwithstanding the correct knowledge of the usefulness of the filter and in face of opinions of the city engineer and superintendent of water works that suitable well water could not be obtained in sufficient quantities, and with only two days' supply in the reservoir on March 14, 1905, that public sentiment allowed such dillydallying in this important matter.

Wells were drilled in many places, — up the Merrimac River near Pine Island, in the easterly portion of the city at Sow Brook, on the south side of the Merrimac River as far south as Cold Spring, and in the Shawsheen Valley in Andover. Some of the wells did not produce sufficient water and some contained too much carbonic acid or too much iron. For one reason or another none of the sources were found suitable. It seemed, however, to be against public opinion to give up the idea of well water, even when the drilling concern had acknowledged the improbability of success, and the investigations were continued and more money spent. Many reports were received from well-drillers, from interested persons, and from the State Board of Health; the latter finally concluded that none of the places considered were acceptable for the purpose of obtaining a water supply. The total cost of these

experiments and studies was $5 764.44, and they extended over a period of eight months and into the late fall.

During the early spring, and about the time it was first thought of obtaining water from driven wells, the water supply committee of the legislature held a hearing, at which it was recognized that conditions at Lawrence were deplorable. Although the hearing developed these conditions, the city government was given one week to act. Upon failure to so do, the legislature ordered the city of Lawrence, through its mayor and board of aldermen, to construct, within a year, an adequate filter, or temporarily obtain water from the surrounding towns. This legislative act is so unusual that it is given as follows:

CHAPTER 389 OF THE ACTS AND RESOLVES OF MASSACHUSETTS LEGISLATURE OF 1905.

An act to provide for an increased water supply for the city of Lawrence.

Be it enacted, etc., as follows:

SECTION 1. The city of Lawrence, acting through its mayor and aldermen, shall forthwith increase the capacity of its works for filtering the water of the Merrimack River to such an extent as to insure at all times a sufficient quantity of water for the use of the public in that city, or it may take water from any spring, pond, or well, in Andover, North Andover, Tewksbury or North Reading; provided, that no source of water supply for domestic purposes shall be taken or used under this act without the approval of the State Board of Health, and that the location of all filter galleries and wells, and the design of filters, shall be approved by the State Board of Health; and provided, further, that if water shall be taken directly from any pond or stream other than the Merrimack River, it shall be used only for the period of one year from the date of the passage of this act, and only in such quantities as the State Board of Health may deem necessary.

SECT. 2. Said city is hereby authorized and directed to raise and appropriate, in such manner as the city council shall determine, such sums of money as shall be requisite for carrying out the provisions of this act; and, if the city council shall so determine, the city may incur indebtedness for the purpose of obtaining money to such an amount as may be necessary for carrying out the provisions of this act, and may issue bonds, notes, or scrip therefor.

SECT. 3. The city of Lawrence shall pay all damages to property that may be sustained by any person or persons by the taking of the waters of any stream or pond as authorized by this act, or insofar as the said city may diminish the flow in any stream or pond, or by the taking of any land, rights of way or easements, or by the erection of dams or the construction of any aqueducts, waterways or other works for the purposes of this act; and such damages shall be assessed and determined in the manner provided by Chapter 48 of the Revised Laws.

SECT. 4. The towns of Andover, North Andover and Methuen, or any one of them, are hereby authorized to contract with the city of Lawrence for a supply of water upon such terms and for such periods of time, not exceeding one year from the date of the passage of this act, as may be agreed upon by the mayor and aldermen of said city and by the selectmen of the town entering into the contract.

SECT. 5. The supreme judicial court shall have jurisdiction to enforce the provisions of this act.

SECT. 6. This act shall take effect upon its passage. (Approved May 10, 1905.)

Inquiries made during the early summer and formal requests made to each of the towns of Andover and North Andover in the late fall, brought the same results as before, namely, that no relief was to be obtained from these sources. The prevalent belief among the officials of these places seemed to be that such temporary arrangements would be used to secure permanent rights.

In August, 1905, it was suggested that the cleaning of the under-

drains of the filter, such as had been done at a prior date, in 1899 and in 1900, would be a benefit. A few drains were examined, disclosing about the same character of clogging material as was noticed when this work was done before. The project was abandoned, however, for fear that disturbance at this time would be unwise.

1906 Results. The winter of 1905–6 was less severe than the few previous ones, so that the conditions did not reach such a critical stage. In the spring of 1906, however, the agitation for a new filter was renewed, after more legislative and public hearings, in which the conditions and need of a new filter were made plain. The legislature, through its Committee on Water Supply, discussed taking action, but waited, giving the city opportunity. After some discussion, upon March 28, 1906, the city council authorized a loan of $70 000 for the construction of a filter. Upon May 25, 1906, bids were received and contract awarded to Michael O'Mahoney, a long-time Lawrence citizen, for the construction of a filter, at an estimated total of $47 543.

The work was started on May 28, 1906, with every prospect that the filter would be in use by November 15, the date set for its completion. Many delays, however, occurred, as the contractor had to abide by an ordinance of the councils to use local labor entirely; and in the early part of November it became evident that completion on time was not possible, and the city councils gave the contractor permission to employ labor from outside the city. Winter came on, however, with the filter uncompleted, and as the winter was a severe and cold one, there was no alternative left but to again apply to the neighboring towns for a temporary supply. In order that the previous objection of illegality could not now be brought up, there was an enabling act passed by the legislature authorizing such temporary use.

Temporary Supply. This action in obtaining water from the surrounding towns is an interesting example of what can be done under pressure. Upon December 16, 1906, the Water Board called attention to the danger and the immediate necessity for securing an additional supply. Upon December 18 there was a conference with the officials of North Andover, and a special election was ordered upon January 1, 1907. The vote, however, was strongly

against supplying the city of Lawrence with water. A special election was authorized in Andover upon January 7, and the vote was almost unanimous in favor of giving aid. The water from Andover was turned into the city main on Friday, January 11.

On February 5 attention was again called to the low water in the reservoir, and upon February 6 a conference was held in Boston, between a local committee from the Lawrence city government and the Water Supply Committee of the legislature, together with members from the State Board of Health. Recognizing the necessity, a bill was introduced and passed in the legislature upon February 7, and signed immediately by the governor, which authorized the town of North Andover to temporarily supply the city of Lawrence with some water from Great Pond. Upon February 14, water from the town of North Andover was turned into the piping system of the city of Lawrence, and, with this help, the water in the reservoir gained and was not again lowered to the danger limit. There was about 50 000 000 gallons obtained from Andover, at a total cost of about $4 500. There was about 37 000 000 gallons obtained from North Andover, at a cost of about $5 500, making the total expense to the city of Lawrence for this lack of forethought and lack of paying attention to proper advice, $10 000, which includes cost of connections.

On April 3, 1907, occurred an accident which caused a set-back in the progress. This was due to a section of the filter roof collapsing, which will be considered in detail by Mr. Sanford E. Thompson.

The entire filter was completed and water turned on November 5, 1907, about one year behind time. At first the filter was run at a slow rate and it was about two months, or January 4, before the State Board of Health allowed the water to be used as a drinking supply by the people, and it is advised that for some time the rate of filtration shall not exceed 1 000 000 gallons per day.

DESCRIPTION OF THE NEW LAWRENCE FILTER.

General. This filter is located directly west of the old one; a portion of it is south of the boiler house and comes close to the foundation. It extends westward, covering an area of about three quarters of an acre. It also extends out into the river bed

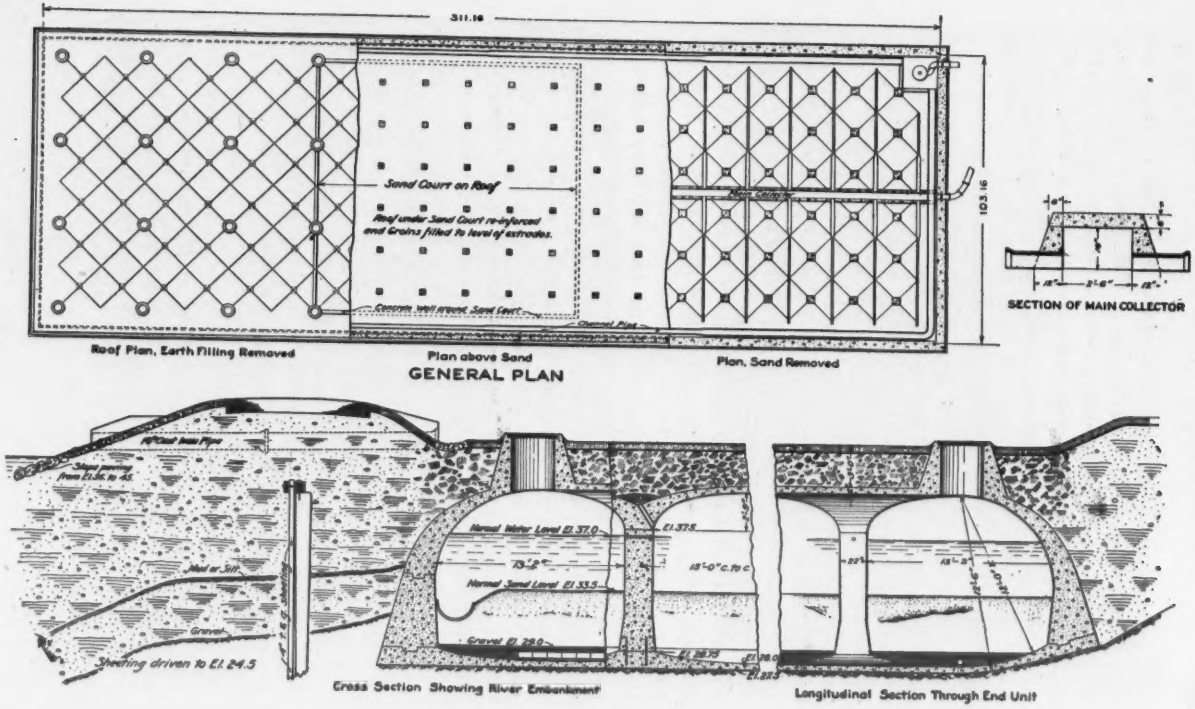

311.16
Sand Court on Roof
Roof under Sand Court re-inforced and Grains filled to level of extrados.
Concrete wall around Sand Court
Channel Pipe
103.16
Roof Plan, Earth Filling Removed
Plan above Sand
Plan, Sand Removed
GENERAL PLAN
SECTION OF MAIN COLLECTOR
Normal Water Level El 37.0
Normal Sand Level El 33.5
Gravel El 28.0
Mud or Silt
Gravel
Sheeting driven to El 24.5
Cross Section Showing River Embankment
Longitudinal Section Through End Unit

FIG. 2.

and a new embankment was constructed along the shore of the river from the material of excavation. (See Plate I, Fig. 2, and Plate II, Fig. 1.) The amount of excavation was about 35 000 cubic yards, and the concrete amounted to about 2 900 cubic yards.

The filter is 21 bays long and 7 bays wide, the bays being 15 feet from center to center of the piers. A general plan and sections are shown in Fig. 2. There are various manholes in the roof for the purpose of letting light into the filter and also to serve as ventilators. Originally it was intended to have the usual sand incline and entrance in the easterly end that has commonly been constructed for filters of this type. With the advances in the method of handling sand, it was thought that it would never be necessary to use wheelbarrows; therefore, a rectangular monitor entrance was constructed, by which it will be possible to have access into the filter. For the purpose of taking out sand that has been scraped it is proposed to use pipe lines in connection with the ejector system. In addition to this, and in order to provide for a storage place for sand upon the roof, an area of 6 bays each way, in the middle of the filter, was reinforced with cross lines of $\frac{3}{4}$-inch steel rods, spaced 9 inches apart, center to center, and also an additional amount of 3 inches of concrete was placed over the entire surface and leveled over the piers, with a filling of cinders 12 inches thick and a concrete pavement on top. Concrete walls were also placed about this area in order that the sand should be confined and not scattered over the sod which will cover the remainder of the roof. Sand will be returned through the openings in the roof. (See Plate II, Fig. 2.)

The river embankment has a core of sheeting in order to make it tight and to aid in keeping the water out during the construction. Some water was encountered in the bottom, but an 8-inch pump working part of the time was sufficient to take care of it. The sub-grade was generally of good material, especially when the ground was well drained. Some little trouble was occasioned in a few places in placing concrete on the bottom; these places were later thoroughly repaired. In order to take care of the upward pressure of the water whenever the filter may be drained while the river is high, gravel drains were laid to pipes all coming

FIG. 1. Cofferdam Construction and Excavation, August 9, 1906.

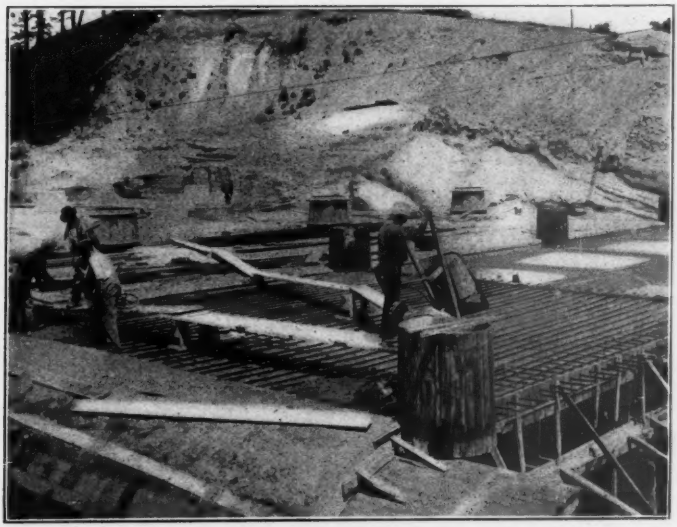


FIG. 2. Method of Reinforcing Roof for Storing Sand, July 5, 1906.

into one central pipe 24 inches in diameter and filled with coarse gravel. This pipe projects upward through the floor and through the bed of sand. This will allow the pressure under the floor to be relieved and the excess water to flow out over the surface of the sand in case such conditions occur.

Details. The details of the filter construction are those of the usual type of groined arch roof, with inverted groined floor, taking the load from piers spaced 15 feet apart. The roof is 6 inches thick at the crown, with a rise of 2 feet 9 inches and a depression at the piers of 20 inches. The floor is 6 inches thick midway between piers, with a greater thickness of 15 inches underneath the piers. The piers are 22 inches square, with chamfered corners, and battered below the sand line so that they are 30 inches square at the base. The water which collects upon the roof of the filter, and above on the slope, will be taken down through openings in the piers and be filtered.

Water is brought to the filter from the gate house which supplies the old filter through a 20-inch pipe, and in through a controlling valve operated by a float, upon the surface of the sand. In order to thoroughly distribute the water and not cause disturbance of the sand, half-channel pipes are placed along the sides of the filter to receive the water as it comes in the inlet channel. (See Plate V, Fig. 2.)

The main drain which takes the water away from the filter is a concrete structure of box shape, with vertical sides and a flat slab roof; it is large enough for a man to crawl through. Twelve-inch half-tile pipes enter this at the center of each bay and extend one bay toward the side walls. From this point there are 6-inch pipes entering these 12-inch half-pipes. (See Plate VI, Fig. 1.)

The filter sand is supported on the drainage gravel, which averages 1 foot in depth. The lower 7 inches ranges from about 3 inches to 1¼ inches in size. The next 2½ inches in depth is of gravel running from 1¼ inches to ⅜ inch. Above this there is 1½ inches of washed roofing or pea gravel running from ⅜ inch to a little smaller, followed by 1 inch of coarse sand. Gravel of the pea size was required to be washed before being placed; other gravel was found sufficiently clean. Filter sand was placed to an average depth of 4½ feet and, according to certain requirements which

were specified, was from about 0.22 to 0.28 millimeter in effective size. (See Plate VI, Fig. 2.)

Materials. The cement used on this work was Atlas Portland cement and was of the usual good quality. The results of the tests, grouped by weeks according to the period of setting, are given in Table No. 22.

The sand and gravel for making the concrete was obtained partly from the excavation, partly from the adjoining hillside, and partly from a nearby bank. It was generally good material with a slight tendency toward fineness and with some clayey material in the gravel. This, as will be pointed out by Mr. Thompson, may have had some slight effect upon the strength of the concrete.

The filter gravel was obtained partly from excavation and partly from a nearby bank on Hancock Street near the place where the filter material was obtained for the first filter. The filter sand was obtained from the same bank, and, to a considerable degree, was obtained without any washing, but simply by screening as it came from the bank. The analyses given in Table No. 23 show the condition of the sand and about what proportion was required to be washed. Table No. 24 also shows the time which it took water to pass through a sample of the sand contained in a standard tin, this being a quick means of determining whether the sand was suitable for filtering purposes. About five times per day a check was made upon general average samples of the whole body, by mechanical analysis. The State Board of Health made check determinations from time to time.

Costs. The canvas of bids for this work is given in Table No. 25, and shows the details of the prices bid by the six different contractors, also giving the engineer's estimate made prior to receiving bids. It is interesting to note that there are three bids which total below the engineer's estimate and three bids which run above this; also that the prices of the lowest bidder are about one half of the highest, with the average of the total costs of about $2 500 higher than the engineer's estimate. The greatest variations occur in the items of cofferdam, excavation, and concrete, and are about the same proportions as the variations in the totals.*

* A copy of the final estimate is given in Table No. 26.

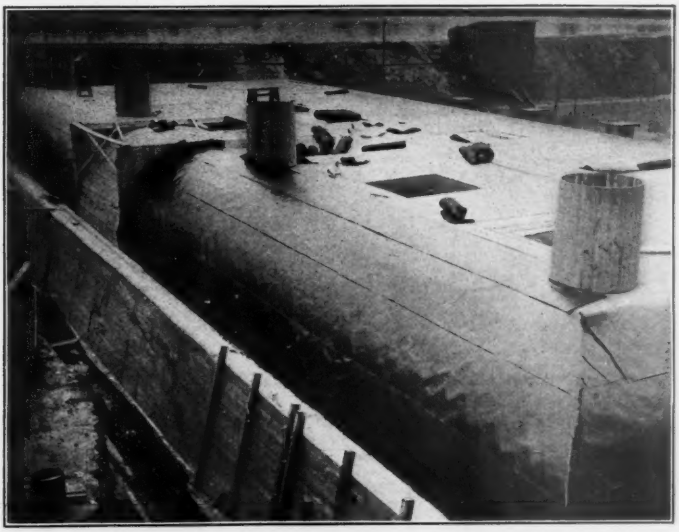


FIG. 1. View of Barrel Arch and Outside Wall, Nov. 1, 1906.

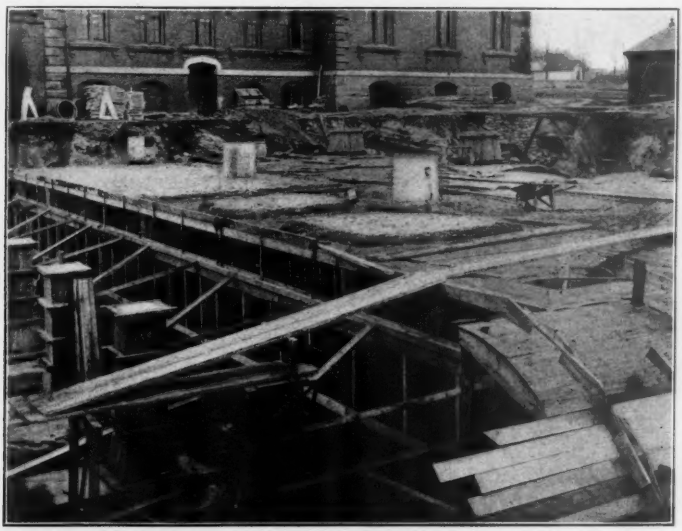


FIG. 2. Forms for Piers and Vaulting, looking Northeast, Nov. 15, 1906.

FIG. 1. General View of Construction, looking East, Nov. 1, 1907.

FIG. 2. Piers and Forms for Vaulting, looking West, May 24, 1907.

FIG. 1. Outside Bay of Filter Interior, Aug. 29, 1907.

FIG. 2. Outside Bay of Filter, Sand in Place, showing Distributing Trough, Nov. 4, 1907.

FIG. 1. Main Collector, Laterals and Under-drainage System, Sept. 16, 1907.

FIG. 2. Three Layers of Filter Sand, also No. 4 Gravel, Oct. 15, 1907.

FIG. 1. Finished Surface of Filter Sand, Nov. 4, 1907.

TABLE No. 22.

Tests of Atlas Cement Used in Lawrence Filter.

FOR WEEK ENDING DATE GIVEN.

One-Day Tests.

Mixed During Week Ending	Per Cent. of Water.	Time in Air, Days.	Time in Water, Days.	Per Cent. of Sand by Weight.	Tensile Strength.	No. of Samples.
Aug. 11, 1906.	18	0	1	Neat	350	9
Sept. 15, „	16	0	1	„	468	10
„ 22, „	16	0	1	„	561	10
„ 29, „	16	0	1	„	308	5
Oct. 6, „	16	0	1	„	380	15
„ 13, „	16	0	1	„	388	5
„ 20, „	16	0	1	„	362	15
„ 27, „	16	0	1	„	326	5
June 8, 1907.	18	0	1	„	261	5
„ 15, „	21	0	1	„	234	10
July 20, „	20	0	1	„	283	5
„ 27, „	18	0	1	„	263	5
Average,					364	

Seven-Day Tests.

Aug. 11, 1906.	18	1	6	Neat	688	6
Sept. 15, „	16	1	6	„	730	5
„ 22, „	16	1	6	„	629	15
„ 29, „	16	1	6	„	823	5
Oct. 6, „	16	1	6	„	790	5
„ 13, „	16	1	6	„	813	10
„ 20, „	16	1	6	„	653	5
„ 27, „	16	1	6	„	738	15
Nov. 17, „	17	1	6	„	745	10
Aug. 11, „	24	1	6	300%	274	2
Sept. 22, „	24	1	6	300	148	5
June 1, 1907.	18	1	6	Neat	636	5
„ 8, „	18	1	6	„	493	5
July 6, „	16	1	6	„	676	5
„ 13, „	22	1	6	„	516	5
„ 20, „	22	1	6	„	515	5
June 15, „	22	1	6	300	222	15
Average,				Neat,	687	
„				300%,	210	

Twenty-eight Day Tests.

Aug. 10, 1906.	18	1	27	Neat	868	2
„ 28, „	16	1	27	„	736	5
Oct. 5, „	16	1	27	„	913	5
„ 26, „	16	1	27	„	838	10
„ 28, „	16	1	27	„	749	5
Aug. 10, „	24	1	27	300	256	2
Sept. 21, „	24	1	27	300	235	5
Oct. 5, „	24	1	27	300	167	5
Average,				Neat,	818	
„				300%,	210	

TABLE No. 23.

MECHANICAL ANALYSES AND WATER TIME TESTS OF FILTER SAND FOR NEW LAWRENCE FILTER, 1907.

Date. September.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
20.....	1	Washed.	..	..	.70	.20	3.5
20.....	2	„	..	..	.92	.26	3.5
20.....	3	„	..	47	.90	.28	3.2
20.....	4	„	1	8	.89	.23	3.8
21.....	5	„	..	..	.90	.26	3.4
21.....	6	„	..	..	.91	.26	3.5
21.....	7	„	..	..	.95	.26	3.6
22.....	8	Unwashed.	..	..	.72	.21	3.4
22.....	9	„	..	..	.82	.23	3.6
22.....	10	„	1	2	1.10	.25	4.4
22.....	11	„	1	15	.82	.22	3.7
24.....	12	Washed.	..	48	1.00	.26	3.8
24.....	13	„	..	58	.92	.26	3.5
24.....	14	„	..	..	.92	.24	3.8
24.....	15	Unwashed.	1	21	.91	.23	3.9
24.....	16	Washed.	1	9	.81	.22	3.6
25.....	17	„	..	53	.97	.25	3.8
25.....	18	„	1	16	.77	.24	3.2
25.....	19	„	1	20	.82	.23	3.5
25.....	20	„	..	54	.87	.25	3.4
25.....	21	„	1	6	.93	.24	3.8
Average for week.....				40	.88	.24	3.6
26.....	22	Washed.	1	20	.71	.23	3.1
26.....	23	„	1	14	.97	.25	3.8
26.....	24	„	..	52	1.20	.31	3.9
26.....	25	„	1	9	.84	.26	3.2
26.....	26	„	1	14	.90	.36	3.4
26.....	27	„	1	12	1.10	.25	4.4
26.....	28	„	1	18	.76	.23	3.3
27.....	29	„	1	32	.77	.25	3.1
27.....	30	„	1	15	.71	.22	3.2
27.....	31	„	1	30	.77	.22	3.5
27.....	32	„	1	23	.68	.24	2.8
27.....	33	„	1	22	.65	.23	2.8
28.....	34	„	1	32	.52	.22	2.3
28.....	35	„	1	5	.96	.26	3.7

TABLE No. 23 — *Continued.*

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
September.							
28.....	36	Washed	1	27	.77	.23	3.2
28.....	37	„	1	35	.52	.21	2.4
28.....	38	„	1	25	.81	.25	3.2
28.....	39	„	1	30	.82	.22	3.7
28.....	40	Unwashed.	1	58	.44	.19	2.3
28.....	41	Washed.	1	58	.44	.21	2.1
28.....	42	„	1	34	.72	.22	3.2
30.....	43	„	1	45	.70	.21	3.3
30.....	44	„	1	20	.94	.22	4.2
30.....	45	„	1	20	.72	.24	3.0
30.....	46	„	1	10	.77	.24	3.2
30.....	47	„	1	20	.73	.24	3.0
30.....	48	„	1	18	.72	.24	3.0
30	49	Vein.	..	..	.77	.26	3.0
October.							
1.....	50	Washed.	1	25	.84	.24	3.5
1.....	51	Unwashed.	1	25	.62	.23	2.7
1.....	52	„	1	12	.74	.25	3.0
1.....	53	Washed.	1	26	.81	.23	3.5
1.....	54	„	1	20	.80	.24	3.3
1.....	55	„	1	35	.85	.24	3.5
2.....	56	„	1	35	.81	.22	3.6
2.....	57	„	1	8	.93	.24	3.8
Average for week.....			1	21	.77	.25	3.1
3.....	58	Washed.	1	19	.79	.24	3.2
3.....	59	„	1	16	.90	.25	3.6
3.....	60	„	1	2	.94	.25	3.6
3.....	61	Unwashed.	1	10	.79	.24	3.2
3.....	62	„	1	2	.86	.26	3.3
3.....	63	„	1	2	.84	.26	3.2
3.....	64	„	1	12	.82	.25	3.2
3.....	65	Washed.	..	48	1.40	.31	4.5
3.....	66	„	1	28	.77	.20	3.8
4.....	67	Unwashed.	1	30	.64	.21	3.0
4.....	68	„	1	15	.82	.25	3.2
4.....	69	„	1	10	.82	.24	3.4
4.....	70	„	1	18	.99	.24	4.1
4.....	71	„	1	8	1.00	.27	3.3

TABLE No. 23 — *Continued.*

Date. October.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
5.....	72	Washed.	..	57	.92	.26	3.5
5.....	73	"	1	5	.83	.24	3.4
5.....	74	Unwashed.	..	55	1.00	.27	3.7
5.....	75	"	1	20	1.20	.27	4.4
6.....	76	"	1	27	1.30	.24	5.4
6.....	77	"	1	8	1.20	.25	4.8
7.....	78	Washed.	1	18	.91	.24	3.7
7.....	79	"	1	5	.91	.23	3.9
7.....	80	"	..	44	1.50	.27	5.5
7.....	81	Unwashed.	1	8	1.40	.26	5.3
9.....	82	"	1	30	1.30	.25	5.2
9.....	83	"	..	55	1.30	.28	4.6
9.....	84	"	1	20	1.30	.26	5.0
Average for week.....			1	12	1.02	.25	4.0
October.							
10.....	85	Unwashed.	1	2	1.30	.31	4.1
10.....	86	"	1	16	1.10	.25	4.0
10.....	87	"	1	7	1.50	.31	4.5
11.....	88	Washed.		57	1.30	.27	4.8
11.....	89	Unwashed.	1	30	.93	.22	4.2
11.....	90	"	1	5	1.10	.23	4.7
12.....	91	"	1	13	.97	.25	3.8
12.....	92	"	1	5	.90	.24	3.6
14.....	93	"	1	2	1.40	.25	5.6
15.....	94	"	..	40	1.00	.31	3.2
Average for week.....			1	6	1.15	.26	4.3
October.							
18	95	Unwashed.	1	5	1.10	.28	3.9
18.....	96	"	..	57	.94	.28	3.3
19.....	97	Bank.	..	..	.90	.25	3.6
19.....	98	"	..	..	1.00	.25	4.0
19.....	99	"	..	..	.83	.22	3.7
20.....	100	Washed.	1	34	.74	.22	3.4
20.....	101	"	..	..	.95	.26	3.6
21.....	102	"	1	10	.86	.24	3.5
21.....	103	Bank.	..	..	.91	.23	3.9
22.....	104	Washed.	..	..	.86	.26	3.3
22.....	105	"	..	..	.89	.26	3.4
22.....	106	"	..	..	.89	.26	3.4
22.....	107	Bank.	..	..	.96	.24	4.0
22.....	108	"	..	..	.87	.29	3.0
23.....	109	"	..	..	.80	.23	3.5
23.....	110	Washed.	..	..	.92	.26	3.5
23.....	111	Bank.	..	..	.81	.22	3.6
23.....	112	Washed.	..	..	.91	.26	3.5
Average for week.....			..	..	.90	.25	3.6

TABLE No. 23 — *Continued.*

Date. October.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
27.....	113	Bank.	1	10	.92	.27	3.4
27.....	114	Washed.	..	57	1.00	.27	3.7
28.....	115	"	..	55	1.05	.28	3.7
28.....	116	"	1	27	.79	.22	3.6
28.....	117	"	1	55	.95	.24	3.9
29.....	118	"	1	..	.86	.25	3.4
29.....	119	"	1	2	1.10	.27	4.0
29.....	120	"	..	52	1.00	.27	3.7
29.....	121	"	1	16	.90	.23	3.9
29.....	122	"	1	17	.87	.23	3.6
29.....	123	"	1	10	.88	.25	3.5
29.....	124	"	1	32	1.00	.25	4.0
29.....	125	"	1	30	1.00	.25	4.0
29.....	126	"	1	33	.97	.25	3.8
29.....	127	"	1	35	.92	.24	3.8
29.....	128	"	2	10	.66	.19	3.4
30.....	129	"	1	28	1.00	.25	4.0
30.....	130	"	1	22	.96	.25	3.8
30.....	131	"	1	42	.79	.23	3.4
30.....	132	"	1	41	.93	.24	3.8
30.....	133	"	1	39	.82	.23	3.5
30.....	134	"	1	26	.77	.21	3.6
30.....	135	"	1	44	.89	.25	3.5
30.....	136	"	1	29	.89	.24	3.7
31.....	137	"	1	16	.89	.24	3.7
31.....	138	"	1	12	.91	.24	3.8
31.....	139	"	1	40	.76	.23	3.3
31.....	140	"	1	20	.86	.24	3.5
31.....	141	"	2	7	.79	.22	3.5
31.....	142	"	2	19	.76	.21	3.6
31.....	143	"	1	42	.82	.23	3.5
31.....	144	"	1	26	.82	.23	3.5
31.....	145	"	1	22	.94	.26	3.6
31.....	146	"	1	25	.98	.26	3.7
31.....	147	"	1	52	.77	.21	3.6
31.....	148	"	1	40	.95	.26	3.6
31.....	149	"	1	51	.87	.23	3.7
31.....	150	"	1	25	.83	.23	3.6
31.....	151	"	1	42	.84	.22	3.8
31.....	152	"	1	33	.95	.25	3.8
31.....	153	"	1	40	.92	.24	3.8
31.....	154	"	1	47	.91	.25	3.6
31.....	155	"	1	33	.84	.22	3.8
31.....	156	"	1	40	.82	.22	3.7
31.....	157	"	1	37	.87	.23	3.6
31.....	158	"	1	40	.84	.23	3.6
31.....	159	"	1	23	.97	.24	4.0
31.....	160	"	2	11	.71	.21	3.3
Average.....			1	32	.90	.24	3.7

TABLE No. 24.

WATER TEST OF FILTER SAND FOR NEW LAWRENCE FILTER.

Date.	No. of Samples.	Average Time. Min.	Average Time. Sec.	Minimum Time. Min.	Minimum Time. Sec.	Maximum Time. Min.	Maximum Time. Sec.	No. which were of Washed Sand.
September 20....	10	–	57	–	37	1	47	10
„ 21....	5	–	50	–	46	–	56	5
„ 22....	9	1	13	1	2	1	32	9
„ 24....	9	1	1	–	45	1	26	9
„ 25....	7	1	12	–	58	1	36	7
„ 26....	9	1	11	–	52	1	23	9
Average for week,	8	1	4	–	39	1	27	8
September 27....	10	1	18	–	56	1	32	10
„ 28....	8	1	34	1	7	1	55	8
„ 30....	6	1	21	1	10	1	45	6
October 1....	6	1	28	1	12	1	45	4
„ 2....	20	1	12	–	48	1	47	10
„ 3....	14	1	17	–	55	2	3	2
Average for week,	11	1	22	1	1	1	48	7
October 5....	10	1	13	–	50	1	45	0
„ 6....	26	1	25	1	–	1	52	7
„ 7....	18	1	18	–	42	1	45	7
„ 9....	23	1	18	–	45	1	56	4
„ 10....	47	1	21	–	48	1	58	4
Average for week,	25	1	19		49	1	51	5
October 11....	31	1	19	–	55	1	46	2
„ 12....	32	1	18	–	53	1	45	4
„ 13....	61	1	21	–	47	1	57	61
„ 14....	32	1	21	–	47	1	56	32
„ 15....	27	1	28	–	51	1	50	27
„ 16....	37	1	21	–	53	1	50	37
„ 17....	50	1	27	–	47	3	–	50
Average for week,	39	1	22	–	50	2	1	30
October 18....	42	1	17	–	40	1	50	42
„ 19....	38	1	18	–	40	1	58	38
„ 20....	19	1	29	–	47	2	14	19
„ 21....	31	1	26	–	38	2	50	31
„ 22....	44	1	29	–	34	2	22	44
„ 23....	47	1	25	–	42	2	22	47
„ 24....	49	1	31	–	37	2	28	49
Average for week,	39	1	25	–	39	2	18	39

TABLE No. 24 — *Continued.*

Date.	No. of Samples.	Average Time. Min.	Sec.	Minimum Time. Min.	Sec.	Maximum Time. Min.	Sec.	No. which were of Washed Sand.
October 25....	42	1	34	–	47	2	24	42
„ 26....	58	1	31	–	52	2	19	58
„ 27....	31	1	41	–	44	2	16	31
„ 28....	9	1	42	1	35	1	58	9
„ 29....	10	1	43	1	35	1	57	10
„ 30....	10	1	43	1	35	1	59	10
„ 31....	34	1	29	–	59	1	48	34
November 1....	22	1	31	–	56	2	5	22
„ 2....	40	1	25	–	52	1	46	40
„ 4....	4	1	33	1	24	1	38	4
Av'r'ge last 10 dys.,	26	1	35	1	8	2	1	26

Note: Test made by placing 10 cubic inches of sand, closely measured in another tin, into a conical receptacle, having a screen at the base of 14 meshes to the inch. Testing receptacle was 3 inches in diameter at top, 2 inches in diameter at the bottom and 8 inches high. A coarse screen, of 6 meshes to the inch, was placed on top of the sand, water was then filled in the receptacle and the time of passage through the sand was noted. Acceptable filter sand allowed the water to pass through in from one minute to one minute and thirty seconds.

TABLE No. 26.

Final Estimate of Construction of Lawrence Filter, December 1, 1907.

Item No.	Items.	Quantity.	Prices.	Amounts.
1	Cofferdam	Lump.	....	$3 600.00
2	Excavation	„	....	11 550.00
3	Slope paving	1 210.5 sq. yds.	$2.50	3 026.25
4	Concrete in floors			
5	Concrete in walls	2 974 cu. yds.	5.57	15 562.58
6	Concrete in piers			
7	Concrete in roof			
8	Roof centers	32 305.6 sq. ft.	0.15	4 845.84
9	Cast-iron pipe	19.15 tons.	70.00	1 340.50
10	Cast-iron specials	4.24 tons.	100.00	424.00
11	Valves and appurtenances	Lump.	.....	500.00
12	Regulating and indicating apparatus	Lump.	.....	500.00
13	Structural work	15 304 lbs.	0.04	612.16
14	Tile drainage system	Lump.	.....	850.00
15	Filter gravel	902 cu. yds.	1.00	902.00
16	Filter sand	4 991 cu. yds.	0.60	2 994.60
17	Entrance	Lump.	.....	1 200.00
18	Extra work			1 538.18
	Total			$49 446.11
	Total cost of filter, including printing, issuing of bonds, and engineering			$54 331.48

TABLE No. 25.

CANVASS OF BIDS FOR CONSTRUCTION OF LAWRENCE FILTER. RECEIVED MAY 30, 1906.

Item Number.	Item.	Quantities.	Engineer's Estimate.	M. O'Mahoney, Lawrence. (Successful Bidder.)	Coleman Bros., Boston, Mass.	Ward & Coombs, Lowell, Mass., and Dover, N.H.	Cole & Holland, Lawrence.	C. E. Trumbull & Co., Lawrence.	Bruno, Salomond & Petitti, Boston, Mass.
1	Cofferdam, etc.	Lump	$7 500.00	$3 600.00	$3 000.00	$10 052.00	$17 420.00	$7 000.00	$10 000.00
2	Excavation	Lump	14 500.00	11 550.00	15 000.00	16 000.00	21 000.00	33 000.00	27 000.00
3	Slope paving	900 sq. yds.	1.50	2.50	1.50	0.75	0.75	1.00	1.50
4	Concrete in floors	900 cu. yds.	7.50	5.57	6.00	8.00	6.00	6.50	8.00
5	Concrete in walls	900 cu. yds.	8.00	5.57	7.00	7.00	6.00	7.50	9.00
6	Concrete in piers	150 cu. yds.	10.00	5.57	8.00	8.00	6.00	9.00	10.50
7	Concrete in roof	950 cu. yds.	7.00	5.57	8.00	8.00	7.50	8.50	12.00
8	Arch centers	32 000 sq. ft.	0.10	0.15	0.10	0.10	0.13	0.10	0.10
9	Cast-iron pipe	20 tons	70.00	70.00	50.00	40.00	55.00	60.00	50.00
10	Cast-iron specials and flanged pipe	5 tons	100.00	100.00	125.00	80.00	100.00	100.00	80.00
11	Gates, valves, and appurtenances	Lump	500.00	500.00	600.00	400.00	300.00	500.00	500.00
12	Regulating and indicating apparatus	Lump	1 500.00	500.00	1 300.00	1 400.00	250.00	1 500.00	1 000.00
13	Structural work, etc.	11 000 lbs.	0.10	0.04	0.04	0.07	0.035	0.05	0.06
14	Tile drainage system	Lump	1 050.00	850.00	780.00	1 500.00	460.70	600.00	2 000.00
15	Filter gravel	800 cu. yds.	1.50	1.00	2.00	2.00	2.25	1.50	1.50
16	Filter sand	5 000 cu.yds.	1.60	0.60	1.00	1.00	1.00	1.25	1.50
17	Entrance	Lump	600.00	1 200.00	150.00	100.00	300.00	100.00	1 000.00
	Total	.....	$64 500.00	$47 593.00	$54 545.00	$64 197.00	$72 175.70	$78 525.00	$85 085.00

The final return of the quantity of filter sand, after settling, was within 9 yards of the estimated quantity.

A detail study of the cost of the filter sand shows that two thirds of the sand was washed and that the remaining third passed examination after screening at the bank. The sand from the general run of the bank gave from 2½ to 4 per cent. finer than 0.13 millimeter, which was the minimum size allowed. After washing, there still remained from ½ to 1½ per cent. of this same fine material. It was thus estimated that about 3 per cent. was lost in washing, which checks very well with the count of the number of loads hauled from the bank.

No accurate data were kept as to the cost of the sand, but some general notes taken may be helpful. It was estimated that the sand was worth 10 cents a yard at the bank, and the cost of the screening, together with the cost of the hauling, added 40 cents. In addition to this there were 6½ cents more for general expenses, including spreading in the filter, making the total cost of the unwashed sand, 56½ cents per cubic yard, delivered in place at the filter. In the same way it was estimated that the cost of the washed sand was 76½ cents delivered in place at the filter. When the shrinkage in the water settlement is taken into account, which amounted to 4½ per cent., or a depth of 0.2 foot, these sums became respectively 59 cents and 80 cents. The bid price was 60 cents.

The cost of the filter sand exhibits in a typical way something about how near the contractor estimated what this work would cost him, and it is probable that upon many of the other items of the contract he made no greater amount of money. Perhaps he even lost. It is unfortunate that public work is frequently let to the lowest bidder because of an erroneous belief or public sentiment that if it is not done, there are ulterior and wrong reasons for doing otherwise. The letting of contracts to the lowest bidder, when he does not receive a sufficient amount of money to warrant his putting capital, equipment, and energy into the job, produces a slow rate of speed, which sometimes causes a municipality to lose in the end, and frequently work is unfortunately and badly delayed. This was the case at Lawrence, where the cost, during the winter of 1906–7, was $10 000 for water

purchased from other towns, and connections, which money could have been saved if this filter had been completed on time. There is no doubt that with energy, well-considered and well-directed efforts, this work could have been accomplished within the time set for its completion.

DISCUSSION.

MR. STEPHEN DEM. GAGE.* During the eleven years that I have been connected with the Lawrence Experiment Station, I have followed the work of the Lawrence filter and its effect upon the health and prosperity of the people of that city very carefully, and I have been very much interested in the able résumé of the subject which Mr. Knowles, Mr. Marble, and Mr. Collins have presented this afternoon. The construction of the Lawrence filter marks an important epoch in the history of municipal sanitation in the United States, in that it was the first filter constructed in this country for the express purpose of reducing the death-rate from a specific disease, typhoid fever. It marks also the first practical application of data obtained from the operation of experimental filters with a given water supply to the improvement of that water supply by filtration. That a reduction in typhoid fever would ensue from the introduction of filtered water in Lawrence was accurately predicted by the results obtained with experimental filters at the Lawrence Experiment Station in 1890 and 1891, and this prediction has been more than fulfilled. In addition, a very material reduction has occurred in the total death-rate of the city, a reduction so different in character from that gradual decrease due to increased appreciation of municipal sanitation which has taken place throughout the state of Massachusetts, and following so closely the introduction of filtered water, that it can only be explained by attributing it to the improvement in water supply. In tabulating the results of the national census of 1900, this decrease in the death-rate was made the subject of special inquiry by the chief statistician of the census bureau, who addressed a letter to the local health officials inquiring if some error had not been made in working up the vital statistics of the

* Biologist, Lawrence Experiment Station, Lawrence, Mass.

city which would account for the sudden drop in many of the death-rates after 1893, as he could conceive of no adequate reason for such a marked reduction.

In the accompanying diagram, Fig. 3, I have plotted the death-rates from all causes and from typhoid fever in both Lawrence and Massachusetts for the twenty-five years from 1881 to 1905. A study of the plotted curves reveals that during that period there has been a gradual decrease in both typhoid and in general mortality in Massachusetts. The Lawrence curves are characteris-

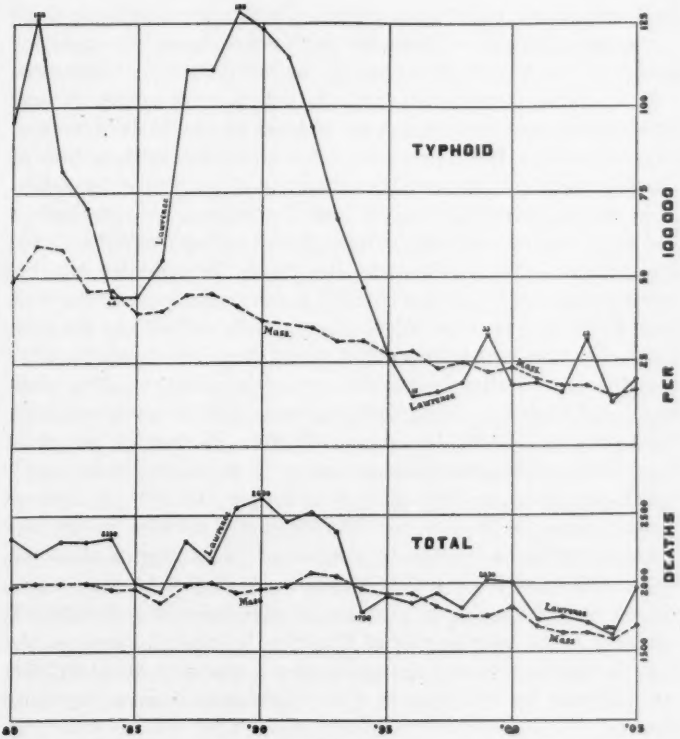


FIG. 3. Comparison of Death Rates in Lawrence and in Massachusetts during Twenty-Five Years.

tically different from the Massachusetts curves. Previous to 1890, the Lawrence curves have an upward inclination, denoting that the total number of deaths, and especially the deaths from typhoid fever, were increasing faster than the population. In 1891 and 1892 the people were warned of the dadger of drinking the city water and many adopted the precaution of boiling the water or began using spring water, and the curves assume a downward tendency from that time, which tendency was made permanent by the introduction of filtered water in 1893.

It will be noted that the typhoid death-rates for Lawrence after 1895 were lower than those for the whole state except in three years, and the cause of these few high points must be sought for outside of the filtered water supply, as Mr. Collins has explained.

It is usually considered that the material prosperity of any municipality is measured in part at least by the healthfulness of its population. Let us consider what effect the introduction of filtered water has had upon the prosperity of the city of Lawrence. It is usually accepted that the loss of a human life represents a loss in the earning capacity of a community of about $5 000. For every person who dies from typhoid fever there are ten who recover but whose illness has entailed a loss to the community of at least $100, or a loss of $1 000 for each death, so that the drain on the community is actually about $6 000 for each death from typhoid fever. During the ten-year period from 1881 to 1890, when unfiltered water was being used, the mean annual death-rate from typhoid fever was 90 deaths per 100 000. During the ten years from 1896 to 1905, when filtered water was in use, the mean yearly death-rate from typhoid fever was 20 per 100 000, an average annual saving of 70 lives per 100 000 by the decrease in this one disease. With an average population of 61 600 during these ten years, this means an actual annual saving of 43.12 lives represented by $6 000 each, or a net gain to the community of $258 700 per year. The average cost of filtration, including interest on the cost of the filter during the same period, was only about $12 000 per year, and the total cost of water-works maintenance, including interest and depreciation, was only about $110 000 per year. In other words, the introduction of filtered water into the city of Lawrence may be said to have caused a yearly saving to the com-

munity of about twenty times the cost of filtration and of more than twice the entire cost of supplying water. A similar computation might be based on the reduction in the total death-rate, when the annual saving would be found to amount to more than one and one-third million dollars, but the decrease in typhoid fever alone has yielded an ample return on the money invested in the filtration plant and fully warrants such extensions and improvements in the plant as are necessary to keep pace with a rapidly increasing population.

Mr. M. F. Collins. When Mr. Gage called your attention to the curved lines, showing the death-rate from typhoid fever in Lawrence before and after the building of the filter, the high points for the years 1903 and 1907 were especially noted. I feel that the increase in typhoid fever cases in the years 1903 and 1907 calls for some explanation. In 1903 the Lower Pacific Mill had 43 cases reported. The local Board of Health called the attention of the state board of health to the conditions existing at the above mill, and the state board delegated one of their corps of assistants to investigate and locate the cause if possible. It was found that the check valve which was placed between the city mains and their mill supply was leaking. The mill authorities were notified to place another check valve within a few feet of the other, which was done, and no further complaints were received from that source.

During the year 1907, in the Washington Mills, from January 28, to March 1, there were 48 cases of typhoid fever and 7 deaths from this mill alone, thus greatly increasing the number of cases for the year. After several of these cases had been reported, the local Board of Health investigated the condition of affairs there and insisted on the mill authorities providing better facilities for supplying pure drinking water for their help. After these improvements had been made this epidemic ceased and there has been no unusual number of cases there since. The following table gives the number of cases and deaths from typhoid fever and the tributary causes as far as they could be ascertained at the time.

TABLE No. 27.

TYPHOID FEVER FOR 1907.

Months.	Cases.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.	Deaths.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.
January	15	3		8	1	15	0					0
February	51		3	39	4	51	6			6		6
March	5	1	1	1	1	5	3			2		3
April	9		1	4	1	9	1					1
May	5			3		5	2			1		2
June	3			1		3	1					1
July	6			3		6	2					2
August	7	1		4		7	0					0
September	8	3		2	1	8	4	2				4
October	6			5	1	6	1			1		1
November	7			2	1	7	1					1
December	7	1	1	4		7	0					0
Total‡	129	9	6	76	10	129	21	2	0	10	0	21

* Canal Water. Persons employed in mills where canal water is used and who may have had access to that water.

† Spring Water. Persons who have used spring water exclusively.

‡ From January 28 to March 1 there were 48 cases and 7 deaths among the employees of one mill in this city, the Washington Mills.

INVESTIGATION OF COLLAPSE OF FILTER ROOF DURING CONSTRUCTION AT LAWRENCE, MASS.

BY SANFORD E. THOMPSON, CONSULTING ENGINEER, NEWTON HIGHLANDS, MASS.

The acquaintance of the writer with the Lawrence filters began towards the latter part of May, 1907, when, at the request of Mr. Knowles, he made an examination and report upon the collapse of a portion of the roof.

The investigation involved an examination of the concrete and the materials composing it, besides a general inspection of the condition of the filter after the collapse.

The concrete was laid in three divisions: First, the floor with its inverted groined arches; next, the columns, which were dowelled to the floor by two pieces of 1-inch iron pipe, projecting about 8 inches up into the column; and finally the roof of groined arches resting upon the columns and supported temporarily upon centering constructed in the usual manner for this type of work.

Various causes delayed the construction, and it was not until the 1st of November, 1906, that any concrete was laid upon the roof. At this time a length of 8½ bays of floor, out of a total length for the entire reservoir of 21 bays, and 8 rows of piers, had been placed.

Of the roof, 7½ bays were laid before the closing down for the winter, as follows:

November 2, 1906 — 2½ bays laid.
November 9, 1906 — 1 bay laid (from 2½ to 3½).
November 23, 1906 — 2 bays laid (from 3½ to 4½).
December 17, 1906 — 2 bays laid (from 5½ to 7½).

The forms for the last two bays (5½ to 7½) were up and ready for concrete on the last day of November, but they waited until the middle of December to get a temperature as high as 28° F. in the morning with prospect of a good day.

As many of you will remember, the fall and winter of 1906–7 were unusually cold, and as this had an important bearing upon the failure, Fig. 1, a curve of the temperature from November 1,

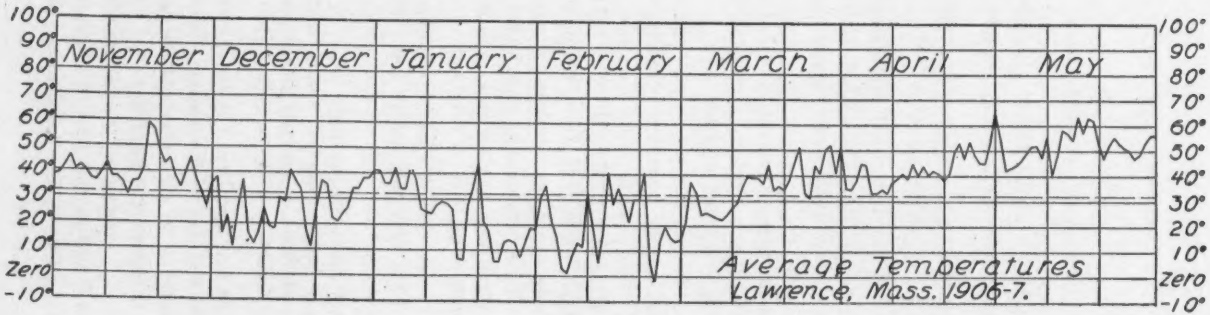

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
Zero
-10°
November
December
January
February
March
April
May
Average Temperatures
Lawrence, Mass. 1906-7.

FIG. 1.

1906, to June 1, 1907, has been prepared. It is seen that the temperature dropped below freezing the last of November, and there was scarcely any real thawing weather until well into March. At the time the last two bays of concrete were laid, December 17, the average temperature was just above freezing, but that night it dropped below freezing and the next day but one reached 6° above zero.

As soon as the concrete was laid in the arches, they were covered with straw to a depth of 6 inches, and later about 2½ feet of sand and gravel were placed on top of the straw, the last two arches being filled upon about two or three weeks after they were laid.

The contract requires, with reference to work in cold weather, General Clauses, Section 23:

"In case any unforeseen contingencies arise which will prevent the work being completed by November 15, 1906, and it becomes necessary to do work in the winter weather, no embankment shall be made and no concrete shall be mixed, nor placed, nor masonry laid, nor any other operation performed, likely to be interfered with by cold, during any of the months of December, January, February and March, and thereafter until the frost is out of the ground, unless permission be obtained from the engineer. If, however, the engineer is of the opinion that any operation can be satisfactorily performed during these months, he may give the contractor a special written permit, which permit shall define the work and the conditions under which such work may be done and such conditions shall be faithfully followed.

"The contractor shall be responsible for all defects in the work done during these months which may arise from the action of the elements, notwithstanding such permit and additional precautions taken. He shall make good such work, and shall make good any work destroyed or damaged by the frost, even though built at any other season of the year."

No permit had been given to the contractor to continue work in December.

A diagram of the easterly end of the filter where the collapse occurred is shown in Fig. 2. To the dotted line this represents a length of about 110 feet out of a total length of reservoir of 313 feet.

The general construction of the forms and the method of placing the concrete is shown in Plate I, Fig. 1. The only lateral bracing, it

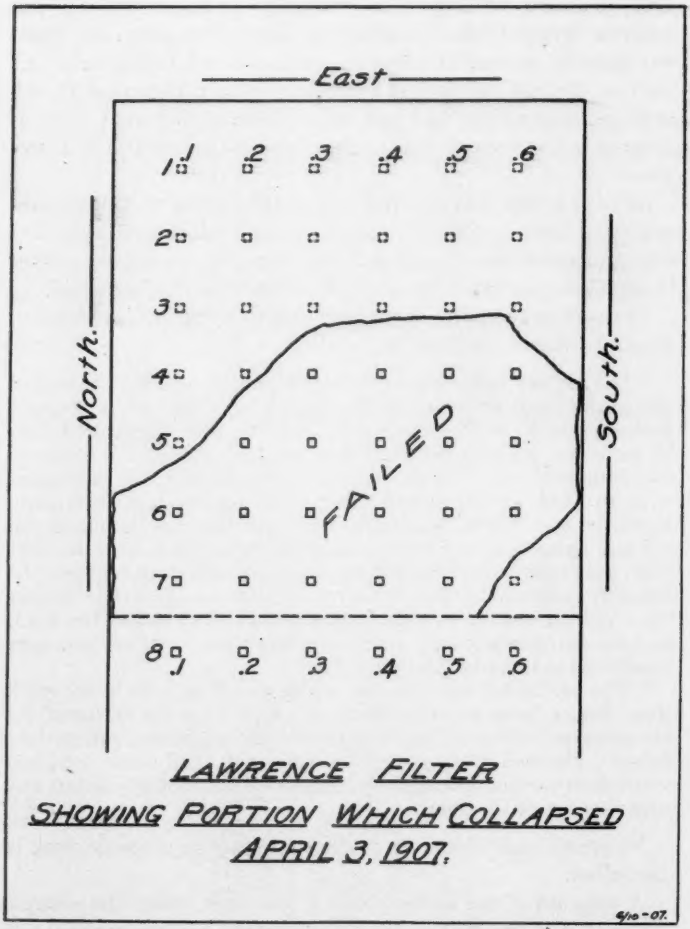


FIG. 2.

will be noticed, consisted of light wooden braces, nearly horizontal, resting against the piers at the height of the second clamp from the top. The only resistance to lateral thrust was therefore that due

FIG. 1. Forms for Roof of Lawrence Filter.

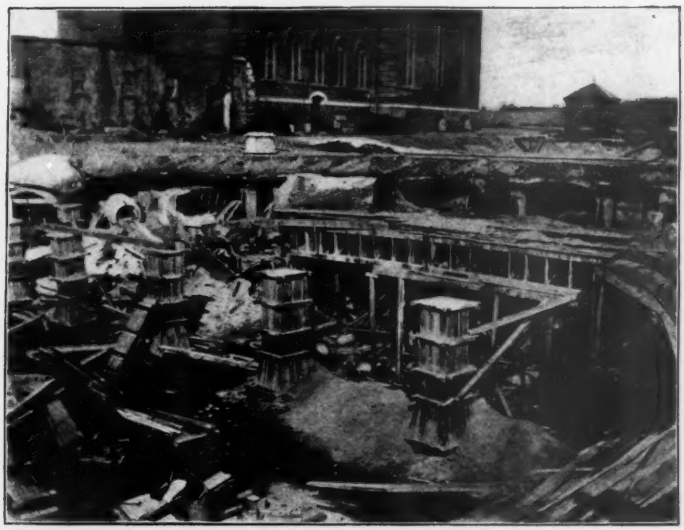


FIG. 2. After the Fall of the Roof.

to the weight of the pier and the adhesion of two short lengths of round rods in the bottom of the pier.

During the winter the centering had been removed from the first three bays of the roof, leaving a length of 4½ bays with the centering in place.

On the day previous to the fall the carpenters began to remove the centers from these last bays, so that at night all the centering was down except the half centers between the seventh and eighth rows of columns, the full centers in the next bay, and the four north arches between the fifth and sixth rows. The foreman carpenter told me that when he came on the next morning, April 3, he noted that a 4 × 8 inch horizontal piece in one of the half centers was twisted, but he did not attach any importance to it. The men began to work on the north arches of bay 5-6 when a cracking was heard, and they all got out from under. The break appeared to start about the center of the reservoir, — that is, about halfway between the two sides, — and the whole roof seemed to go down at once. Fortunately, the men were warned in time and no one was injured.

The visit of the writer to the filter was not until May 23, but the condition was substantially the same then as on April 3, the date of the fall, scarcely any clearing having been done.

The general condition of the reservoir a few hours after the fall of the roof is shown in Plate I, Fig. 2, and Plate II, Fig. 1. All the columns in the last row, line 8, against which the end of the centering was braced, were standing; but one of these columns at about the center of the reservoir and where the break was said to start is slightly canted. In the next or seventh row, four piers were standing, but all of them tipped, including the pier in the row under the southwest arch. The columns in the other rows were nearly all broken. Pier 8.3, which is shown as slightly canted at the time of the fall, was afterward pried over, and the cleavage of the base from the floor was smooth, as one would expect of a joint between concrete laid on two different days. The two steel dowels which projected into the pier had pulled out, leaving clean surfaces.

A view looking northeast after cleaning up the loose concrete and forms is given in Plate II, Fig. 2.

A closer view of the third row columns which were still standing showed that several of them were tipped toward the west, and a crack had opened at the top, that is, at the springing line of the arch, about ½ inch wide. Three were out of plumb from 1 to 2½ inches, and these were also cracked at the base as well as the top. In the portion of the roof remaining, cracks were noticed, mostly along the crown of the arch.

EXAMINATION OF THE CONCRETE.

The concrete at the time of the fall was so soft and crumbly that it could be readily pulled to pieces. At the time of my visit it was fairly hard, evidently having hardened very much since the failure. The stones, however, pulled from the concrete more easily than they should have done in first-class concrete, indicating that even at this time the concrete was not very strong. Concrete from the upper surface of the roof, especially in the thick masses above the columns, was noticeably weaker even at date of my visit than the concrete next to the centers. At the date of reading this paper, ten months after the accident, the samples referred to above are sound and hard.

EFFECT OF MANURE.

In certain places pieces from the top surface of the roof were much discolored. Examination showed that the concrete had been in contact with manure contained in the straw, while other neighboring portions of the roof surface which were covered with clean straw were of normal color. The discolored portions, the color extending to a depth of about 1 inch, were softer than the rest of the concrete and readily flaked when rubbed between the fingers. Although this did not extend deep enough to be in itself responsible for the failure of the roof, the condition was such as to show very conclusively that manure is a bad thing to place in contact with green concrete, and that when straw covering is employed, it should be free from manure.

In this connection the writer may say that he recently had occasion to examine a barn floor of concrete and also several concrete drains in this floor which had been in use for a number of years in continual contact with manure, and found the surface absolutely

FIG. 1. After the Fall of the Roof.

FIG. 2. After Most of the Debris had been Removed.

hard and perfect. A tank containing manure was also in similarly good condition. The conclusion, therefore, may be drawn that manure is likely to injure green concrete, while not affecting well made concrete after it has set and hardened.

SAND AND GRAVEL.

The sand and gravel used for the concrete were from a pile which had been excavated from the site of the filter. This material was screened into gravel for the coarse aggregate or ballast, and sand. Four samples of the sand were taken, and two samples of the screened gravel. Examination of the sand and of its analyses shows that it is all of medium quality, containing a somewhat excessive percentage of dirt for maximum strength, but none too much for water-tightness. Examination of the analyses of the gravel shows a large percentage of material under ¼ inch, the sample with the least fine material screening 20 per cent. below ¼ inch, although the contract specifies (Section 28), that, "all particles smaller than one quarter (¼) inch shall be screened out." The specifications require proportions 1: 3: 5. If 20 per cent. of the gravel is below ¼ inch, and therefore sand, the proportions are actually 1: 4: 4, thus giving a concrete greatly inferior in density and strength to that required by the specifications. Many of the gravel stones were covered with a coating of very fine clayey sand, which after drying in the laboratory and screening by hand for five minutes did not entirely come off. Tests by Mr. Howard A. Carson (recorded in the Seventh Annual Report of the Boston Transit Commission, 1901, p. 39) show one third greater strength for concrete made from washed gravel than similar concrete made with gravel coated with a thin film of dirt. The excess of fine material tends to make the concrete not only weaker but slower in setting and hardening.

The contract specifies (Section 28) that the gravel "shall be washed if necessary to render it sufficiently clean," but this was not done.

EFFECT OF LOW TEMPERATURE.

The temperature records taken at Lawrence during the winter of 1906 indicate only a very few days at which the temperature was above freezing.

As already stated, the last arches were not laid until December 17. On the following day, as shown by the curve in Fig. 1, the temperature dropped below freezing, and there were only a few days when the temperature was above freezing before the earth covering was placed. The covering naturally tended to equalize the temperature, so that the concrete would not then have the full benefit of the occasional warmer days during the winter and early spring.

It is common knowledge that continued cold prevents concrete from reaching its normal growth in strength. Tests at the Watertown Arsenal * and elsewhere, the results of which are readily available, have brought out this point clearly, showing that if the temperature is maintained below freezing the cement after several months has only a fraction, — on the average we may say about ½, — the strength that it would have reached with a temperature of 70° F. Even a temperature as high as 39° F. retards the hardening so that the strength may not be more than two thirds of what would be attained at 70° F. As soon as any of the specimens were removed from the cold and placed in a warmer temperature the hardening was accelerated, and a strength nearly normal was soon reached.

At Lawrence the effect was similar, the concrete rapidly gaining strength after exposure to the warmer atmosphere in April and May.

CENTERING.

The contract specifies, Section 58:

"The contractor shall notify the engineers when he proposes to strike centers, but no centers shall be struck opposite the outside walls until the embankment has been completed to the springing line, and no other centers shall be struck until at least five (5) rows of vaulting beyond have been completed."

The five rows of centering which are required to remain in place at all times are evidently for the purpose of allowing the concrete to set and also to take up the thrust of the arches due to temperature or unequal loading. The contractor evidently assumed that

* Taylor & Thompson's "Concrete, Plain and Reinforced," p. 412.

the provision was only for the purpose of giving time for the concrete to set, for he was removing the forms with no diagonals left in place, except a few braces placed against a row of piers, which had only their own weight to keep them in an upright position.

Without attempting to analyze the thrust of the arches, it is evident that if the half center at the end had been loaded with earth to the full height, it would have balanced the pressure from the next arch, so that the line of thrust from all the arches would have come directly into the piers. However, in filling a roof like this, the earth cannot be carried square to the edge, but slopes off, probably in such a case as this at a slope of 1 to 2, or 1 to 3, so that there must be a thrust from the arches beyond it if they are unsupported.

The assumption that the thrust was a factor in the fall is strengthened by the facts that (1) one half of the bay between column rows 3 and 4 was laid as late as November 23, thus having only twelve days more to set with the temperature slightly above freezing than the outer bays, and yet this bay suffered the removal of the forms without apparent damage; (2) the bay between column rows 5 and 6, half of which was laid on the final date, December 17, 1906, did not fall on the day when the forms were removed from the first portion of it, although unreinforced concrete falls quickly with but slight warning; (3) warning of failure was given by cracking of the centers and apparently commenced in about the middle of the reservoir, near pier 8.3, which was tipped from the thrust of the diagonal braces against it.

CAUSES OF FAILURE.

The data presented enable us to reach definite conclusions in regard to the causes which contributed to the failure.

The design of the groined arch roof is one universally endorsed, being similar to that adopted with satisfaction in many other filters built from the year 1895 to the present time. It is consequently impossible to attribute the failure of the Lawrence filter roof in any way whatsoever to the design.

The causes of the failure therefore must lie in the construction. After removal of the forms supporting the roof the fall appears to

have been due to a combination of two causes, neither of which alone would probably have occasioned the accident.

(1) The thrust of the arches.

(2) The weak condition of the concrete because of

(*a*) Low temperature, which retarded the hardening;

(*b*) Improper screening of gravel, producing an excess of sand which tends to make concrete slow in hardening;

(*c*) Dirty gravel, reducing the strength of the concrete.

All of these causes were probably contributory to the fall. The subsequent hardening of the concrete indicates that no trouble could have ensued if the forms had remained for a longer time and until more arches had been placed.

REPAIRS.

The wrecked portion of the roof and the broken piers were removed, and replaced by a new structure built to the same design. The arches which remained standing, but which were cracked and had separated along the crown, and the piers supporting them, which were slightly tipped, were thrown back into place by jacking up the arches vertically, and at the same time jacking them horizontally to bring them into place, close the cracks, and plumb the piers.

PRODUCER GAS PLANTS.

BY HENRY CROWTHER,* PHILADELPHIA, PA.

[A discussion on paper by Harry L. Thomas, read January 8, 1908.]

We have installed gas-producer plants up to 800 and 1 000 horse-power. We are doing more of this in the West than in New England. We have installed for the American Locomotive Works, at their Richmond shops, a 500 horse-power gas-producer plant which is developing 160 000 000 foot-pounds per 100 pounds of coal. For the Pennsylvania Railroad, near Wilmington, we have installed two 100 horse-power gas-producer plants driving 100 horse-power Westinghouse engines. At Poughkeepsie, N. Y., and at New Orleans, we have installations of gas-producer plants. The duty developed has ranged from 120 to 140 and 160 million per 100 pounds of coal.

Mr. Thomas hit the nail on the head when he said, in summing up, that, after all, experience is necessary in running these plants. This is no trick after a man has had some experience, but it is impossible to expect a steam engineer, or a steam boiler fireman, to take hold of one of these plants and run it offhand. There are certain precautions to be observed, the principal of which are, — that your coal should be of as uniform a character as possible, and it should not exceed a certain per cent. of hydrogen, say about 18 to 20 per cent., because if you exceed that you get back firing. This was the cause of Mr. Thomas' trouble; he struck there a coal with a high per cent. of sulphur, which, if persisted with, would have pitted the engine so badly in the course of a few weeks that he would have had to renew the parts. These are points which come with practical experience.

The economies of producer gas plants are so manifest that, in the West particularly, where they seem to have taken these things up more extensively, they are being rapidly adopted, and up to large units. We haven't put in anything over 1 000 or 1 200

*With R. D. Wood & Co.

horse-power yet, but they are building now for the United States Steel Corporation gas engines up to 4 000 horse-power; they operate either on natural gas or blast-furnace gas, but they could be operated on producer-gas with by-product recovery. This, however, is only possible in large units, 3 000 or 4 000 horse-power and upwards. The whole thing sums itself up when you can show an economy of from three to five times what a steam engine will give you. When you can develop, as has been done, 20 horse-power for one cent an hour per horse-power, with coal at $1.50 a ton, the fact is forced upon you that the gas-producer with the gas engine is going to be, and is already, a very active competitor of the steam engine, and is bound ultimately to force it out.

The chief engineer of the Pennsylvania Railroad told me last year that in the opinion of their engineering department the steam turbine was only an intermediate step between the steam engine and the gas engine. It must be remembered, if you please, that steam boiler men and steam engineers are a development of a century of progress, and they know these things by rote. If you will give the same amount of attention to the operation of your gas engine and gas-producer as you have given to your steam engine and steam boiler, there will be no difficulty in their operation. And while, as one gentleman very aptly said, we had better bear the ills we have rather than flee to those we know not of, yet, at the same time, those latter ills are more apparent than real, if you get right down to it.

In Poughkeepsie the saving effected by the gas-producer plant over the old steam plant paid for the cost of the plant (about $4 000) inside of twenty-two months. They saved at the rate of about $185 or $200 per month, in comparison with what they had been paying before with a steam engine and steam boiler.

THE PRESIDENT. I should like to ask Mr. Crowther what is really the best type of fuel to use in these plants.

MR. CROWTHER. Anthracite coal, undoubtedly. Anthracite gives you a clean gas; the B.t.u. runs about 140, and you have no trouble with cleaning.

The report of the United States Geological Survey, which can be had from the government, shows that at the government testing

station at Forest Park, St. Louis, they tested out lignite, peat, wood, straw, coke, charcoal, — everything, in fact, that could be burned, — and yet they got back to the fact that anthracite coal is the best fuel for all purposes. But bituminous coal (if you don't get it too slack), or even run of mine, with automatic cleaners, is all right, although in that case, when you have to put tar cleaners in, it involves additional cost, of course. Therefore anthracite remains the best. In other words, the best fuel is that which is free from the hydrocarbons — a high percentage of hydrocarbons.

MR. THOMAS. Mr. President, if I may be excused for speaking about one other thing which is brought to my attention, which I omitted in the paper, the matter of feeding the generator: perhaps you all understood clearly how our generator is fed, — we clean the fire and fill the generator once in three hours. Under good practice that is as often as it is necessary to do it. Sometimes, if the coal is running rather poor, we have to clean it every two hours and a half, but we usually clean it every three hours. And whereas we were advised in the first place to sift the ashes and put them back, our experience has taught us there is no economy in doing that, for while it may cut down the record of the coal for a day's run, it will make so much ash and dirt in the fire that the additional coal used the next day will make up what you did not use that day. So we simply take that and put it on one side, and we contemplate shaking it out and burning it under our steam plant to get rid of it.

MR. CROWTHER. With proper handling a gas-producer can be started with the engine in about an hour to an hour and a half, and when the fire has been simply let stand it only requires a few minutes over night.

At our works at Camden we have gas-producers coupled to different makes of engines, and our men, naturally having had much experience, have no difficulty in starting promptly. If it took a day to start a fire in order to get gas from a producer to an engine, the company making them had better go out of business. The statement quoted by Mr. Thomas is far-fetched, and the man who made it did not understand his business. That is the only charitable remark that can be made about that.

MR. FARNUM. Mr. President, I would like to ask how many

men it takes to run this plant, and if there is any economy in that direction.

MR. THOMAS. In the matter of attendants, our plant is exactly the same as the steam plant, — one man takes care of the plant at both places; it takes but one man.

MR. CASSELL. I would like to inquire if either of the gentlemen can give us the relative cost as between the establishment of a steam plant and this gas plant they are talking about, in an approximate manner.

MR. CROWTHER. Yes. The cost of a gas-producer plant, fully equipped with producer, gas engine, washers, scrubbers, and everything of that sort, as compared with a steam plant, is very nearly a stand-off. There are probably two or three dollars more you might figure on per horse-power, but the increased cost of the gas engine is more than offset by the increased cost of the boiler house, stack, foundations, and that sort of thing, as compared with a gas-producer house. I am speaking of the ordinary sizes, built of corrugated iron, or something like that.

While the cost of the installation of the gas-producer is probably 2 or 3 per cent. more than that of a steam plant, perhaps the cost of maintenance and repairs, on the other hand, is largely in favor of the gas-producer.

Speaking on that very point which Mr. Thomas cited, of getting a gas-producer started, the Erie Railroad at Jersey City has had now for nine years, I think, Westinghouse gas engines running with R. D. Wood producers, and in one of those producers for nine years the fire has never been out; it has never, therefore, required relining with fire brick. So that you can very readily understand the great economy of the maintenance and repair charges. But, roughly, it is about a stand-off; there is very little difference, in large installations.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 11, 1908.

President Alfred E. Martin in the chair.
The following members and guests were present:

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, A. F. Ballou, G. W. Batchelder, F. E. Bisbee, George Bowers, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, C. E. Childs, J. H. Child, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, C. E. Davis, A. W. Dean, M. J. Doyle, E. D. Eldredge, B. R. Felton, A. N. French, C. W. Gilbert, A. S. Glover, F. W. Gow, F. H. Gunther, E. L. Grimes, F. E. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., B. B. Hodgman, H. G. Holden, J. W. Kay, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, J. J. Kirkpatrick, E. E. Lochridge, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, H. A. Miller, William Naylor, F. L. Northrop, O. E. Parks, H. W. Sanderson, P. R. Sanders, E. M. Shedd, G. H. Snell, G. A. Soper, G. A. Stacy, W. F. Sullivan, R. J. Thomas, W. H. Thomas, D. N. Tower, W. H. Vaughn, C. K. Walker, F. B. Wilkins, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall. — 65.

Honorary Member.

Wm. T. Sedgwick. — 1.

Associates.

Allen & Reed, Inc., by Henry W. Littlefield; Anderson Coupling Company, by F. A. Leavitt; Ashton Valve Company, by C. W. Houghton and Charles L. Bucknam; The Fairbanks Company, by F. E. Smith; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; International Steam Pump Company, by Samuel Harrison; Jenkins Bros., by H. F. Fiske; Charles Millar & Son Company, by Charles F. Glavin; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin and J. G. Lufkin; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by F. L. Northrop; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown;

A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. M. Barnard; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by W. F. Woodburn. — 29.

GUESTS.

F. W. Dinwiddie, Gardner, Mass.; George F. Merrill, superintendent water works, Greenfield, Mass.; Charles N. Oakes, Westfield, Mass.; James G. Hill, Lowell, Mass.; John F. Stark, president Pennichuck Water Works, Nashua, N. H.; W. W. Trowbridge, West Newton, Mass.; L. H. Cornfel and W. Burmbain, Boston; Charles F. Chase, Providence, R. I.; William E. Smith and Lettice R. Washburn, New Bedford, Mass.; A. E. Blackmer, Plymouth, Mass.; Thomas G. O'Connell, Wakefield, Mass. — 13.

[Names counted twice — 6.]

The Secretary read the following names of applicants for active membership:

Arthur E. Blackmer, Plymouth, Mass., superintendent of Water Works; George F. Merrill, Greenfield, Mass., superintendent of Water Works; William E. Smith, New Bedford, Mass., member of Water Board; William H. Pitman, New Bedford, Mass., member of Water Board; Lettice R. Washburn, New Bedford, Mass., member of Water Board.

On motion of Mr. Eglee, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants whose names had been read, and he having done so, they were declared elected members.

The Secretary read the following communication:

PHILADELPHIA, February 19, 1908.

NEW ENGLAND WATER WORKS ASSOCIATION,
715 Tremont Temple, Boston, Mass.:

Gentlemen,— Believing that the salvation of the remnant of our forests is one of the most pressing duties of the nation, I respectfully urge your careful and favorable consideration of House Bill No. 10 457, "For Acquiring National Forests in the Southern Appalachian Mountains and White Mountains," and the adoption at an early meeting of resolutions urging this matter upon the Committee of Agriculture, Hon. Charles F. Scott, chairman, Washington, D. C.

Yours truly,

JOHN C. TRAUTWINE, JR.

THE PRESIDENT. The communication has been before the Executive Committee and has been referred to this meeting by action of the committee. I think Mr. Baker has something to say on the subject.

MR. M. N. BAKER. When this matter was brought up in the Executive Committee there was some discussion on the broader subject of the conservation of the natural resources of the country, which subject includes not only the preservation of forests, but the conservation and the development and utilization of the water resources of the country, and also a study of such other natural resources as our coal supplies. As probably all those here know, there was appointed some months ago by President Roosevelt a commission styled "The Inland Water-Ways Commission," to take up, primarily, an investigation of and to map out a scheme for the development of the navigation of the country; but the President very wisely made his instructions to this commission broader, and the commission in its recent report, in accordance with the detailed request of the President, entered upon a consideration of the broad questions of the conservation of the natural resources of the country, giving particular attention to the water resources.

It is unnecessary to elaborate upon this point, but I wish to bring to your attention the fact that the national engineering societies have taken up this matter of the conservation of the natural resources of the country, and that also there is to be held in May, at the call of President Roosevelt, a convention of the governors of all the states of the Union at Washington just about the time of the meeting of the American Water Works Association. And at this conference of the governors with the President there will be a number of papers read, and discussions, and perhaps the formulation of some policy in regard to the conservation and future development of the natural resources of the country.

Now as water-works men and as engineers, the members of this Association are, of course, primarily interested in all that pertains to the water resources of the country, their conservation in quantity and in purity. The bearing of the forestry question upon the water resources of the country is so evident to all that nothing

need be said upon that subject. The Executive Committee of this Association decided to recommend to the Association the appointment of a committee on the conservation and development and utilization of the natural water resources of the country, that committee to consist of five members, appointed by the chair, and to have power to confer with and to coöperate with like committees from the engineering societies or any other associations that might take similar action. Inasmuch as we have a very full program for this afternoon, I will not take up any more of your time, but I think it is evident to all that it is very important that this Association get in line with others and appoint a committee to take this matter into consideration and to coöperate with others.

I might say just one thing more, which will be of particular interest to the members of this body who are not informed of the fact, and that is that there is now under consideration by the United States Geological Survey and by the United States Bureau of the Census, a census of the water-powers of the United States. Such a census, you will remember, was taken in 1880, but it has not been revised since that time, and meanwhile there have been very great developments and very many changes, and it is possible, although not certain, that another census of the water-power will be taken. It will be becoming for this Association, and for its individual members, to do what can be done to further the taking of such a census.

MR. SULLIVAN. I move that the report of the Executive Committee be accepted and adopted, and that a committee of five members be appointed by the President to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country.

The motion was adopted, and the President subsequently appointed the following-named gentlemen as the committee: M. N. Baker, William T. Sedgwick, Leonard Metcalf, Allen Hazen, and George A. Soper.

MR. EGLEE. Would it not seem desirable, Mr. President, that an expression of opinion from this Association should be made at the present time and forwarded as requested? Every one here

is certainly interested in the preservation of the water-power and in the conservation of water supplies, and it would seem as though a resolution passed here, or framed by the committee to be passed before the close of this session, might be of value. The appointment of a committee of five to follow this legislation is, of course, a very good thing, but, as I understand it, we do not meet again until June, which will be after the adjournment of Congress. I would make the suggestion, not as a motion, that a committee of two might be appointed at the present time to draft a resolution, which might possibly be endorsed by this session of the Association, and forwarded to the proper official.

MR. SULLIVAN. This matter came up in the Executive Committee about half past twelve to-day, and after talking it over we thought the time was too short in which to draft any resolutions, and it was the intention of the Executive Committee to have this sub-committee appointed who would take care of that matter.

MR. EGLEE. Would Mr. Sullivan permit an amendment to his motion to the effect that the committee appointed by the President should be empowered to draft a suitable resolution and forward it to the proper officers previous to the adjournment of the present session of Congress?

MR. SULLIVAN. I certainly would accept that as another motion, but my motion has already gone through.

THE PRESIDENT. I understand Mr. Eglee makes this as a suggestion, but I will put it as a motion, that the committee be instructed to prepare such a resolution.

The motion was adopted, and the President announced the committee would govern itself accordingly.

The first paper of the afternoon was read by George A. Soper, Ph.D., consulting sanitary engineer, New York, on "The Typhoid Fever Epidemic at Watertown, N. Y., in 1904." The paper was discussed by Prof. William T. Sedgwick and Prof. C.-E. A. Winslow.

Mr. E. L. Grimes, chief engineer, Bureau of Water Supply, Troy, N. Y., gave a description of the "Troy Water Works Extension."

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, March 11, 1908, at 11.30 A.M.

Present: President Alfred E. Martin, and George A. Stacy, M. N. Baker, Robert J. Thomas, George W. Batchelder, D. N. Tower, George A. King, Michael F. Collins, William F. Sullivan, and Willard Kent.

Five applications were received and recommended for membership, viz.:

William H. Pitman, member Water Board, New Bedford, Mass.; William E. Smith, member Water Board, New Bedford, Mass.; Lettice R. Washburn, member Water Board, New Bedford, Mass.; Arthur E. Blackmer, superintendent Water Works, Plymouth, Mass.; George F. Merrill, superintendent Water Works, Greenfield, Mass.

Messrs. George A. King and D. N. Tower, members of the Committee on the June Outing, presented a detailed report (appended hereto) of the proposed arrangements for same, and on motion of Mr. M. N. Baker the report was accepted and the committee continued. The same committee was by vote authorized to procure a photograph of surviving charter members of the Association on the occasion of the June meeting.

The report of Editor Sherman with reference to a revision of the prices charged for back numbers of the JOURNAL of the Association wasreceived, accepted, and, on motion of Mr. M. F. Collins, it was voted that the recommendations of Mr. Sherman be adopted and that the prices named in his report be and hereby are established. This report is appended to these minutes.

A communication from Mr. J. C. Trautwine, Jr., with reference to forest reserves was received, and, after discussion, on motion of Mr. George A. Stacy, it was voted that the Executive Committee recommend to the Association the appointment of a committee to represent this Association in behalf of the movement to con-

serve the natural resources of the country. Mr. M. N. Baker was delegated to present the subject to the Association.

The subject of the September convention was discussed, but no action taken.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

REPORT OF SUB-COMMITTEE ON JUNE OUTING, 1908.

TAUNTON, MASS., February 29, 1908.

The sub-committee on the proposed outing to Plymouth presents the following report:

The boat from Boston to Plymouth will begin making its daily trips on Wednesday, June 17, and the boat is always crowded on that date. The schedule time for leaving Boston is 10 A.M., and reaching Plymouth at 12.45 P.M.; on returning, leave Plymouth at 3.30 P.M., and reach Boston at 6.15 P.M. The regular fare is $1.00 round trip and 75 cents one way. The management would give us a special rate of 75 cents round trip and 50 cents one way. A lunch counter is provided on boat, and undoubtedly some provision could be made for a luncheon for the whole party.

The New York, New Haven & Hartford Railroad now have a train leaving Boston at 8.43 A.M., via Cohasset, and due at Plymouth at 10.45 A.M., and one leaving Plymouth for Boston via Whitman at 5.56 P.M., and due in Boston at 7.17. Undoubtedly there will be trains at about these hours in June and probably more trains than are now scheduled. A party of one hundred and fifty could be carried in two special coaches on regular trains, but if numbers are considerably in excess of one hundred and fifty, a special train would be necessary.

The one-way fare is 75 cents, but for parties traveling together on specified train the following round-trip prices are made:

50–74	$1.20
75–99	1.13
100–149	1.05
150–199	.98
200	.90

Mr. Blackmer advises dining at Hotel Pilgrim, which is about three miles east of the town at the " Head of the Beach." Dinners could be served at prices running from 75 cents to $1.50 per plate, the price to include electric car ride in special cars from the center of the town. The hotel will probably not open before the middle of June.

Single admission to Pilgrim Hall is 25 cents; in lots of one hundred, 10 cents each, but the one hundred must actually go into the hall. A price of 20 cents each for seventy-five has been made occasionally and could probably be obtained if desired.

The committee visited Plymouth and conferred with Mr. Blackmer, the superintendent of the water works, and in view of his desires and the information given above, we make the following

RECOMMENDATIONS:

That the Association make an all-rail trip to Plymouth on the fourth Wednesday of June (the 24th), leaving Boston at about 8.43 A.M., and going by way of Cohasset, and returning by way of Whitman at about 5.56, to reach Boston about 7.17.

That on the arrival in Plymouth it assemble at the Armory, which is about three minutes' walk from the railroad station, to receive a welcome to the town.

That at about 11 o'clock opportunity be given to visit the following places: Pilgrim Hall, nearly across the street from the Armory; the water-works shop on Howland Street, about three minutes' walk from the Armory, where 18-inch cement pipe will be in process of manufacture; the Rock, monument, and such other places as members may desire to visit; that at 12.45 special electric cars be taken at the Armory for the ride to Hotel Pilgrim for dinner; that on the return from the beach those who desire take the barges, provided by the town authorities, at Town Square and visit the work of laying the 18-inch cement main which is to be laid between Little South Pond, the source of supply, and the pumping station. This work will probably be in progress about two miles south of the town; members who desire to make this trip to notify Secretary before leaving Armory in morning.

There are always plenty of carriages to be hired for 25 cents per passenger for visiting different points of interest in town.

The cost of the trip should not exceed $2.25, based on an attendance of one hundred.

We base our estimate on the following figures:

Railroad fare.....	$1.05
Dinner.....	1.00
Admission Pilgrim Hall,	.10
Printing, tickets, etc....	.10
	$2.25

Respectfully submitted,

(Signed) GEORGE A. KING,
D. N. TOWER,
Sub-Committee.

Report of the Editor on Prices for Back Numbers of the "Journal."

Boston, February 26, 1908.

Mr. A. E. Martin,
President N. E. Water Works Association,
Springfield, Mass.:

My dear Mr. Martin, — In accordance with the understanding at the last meeting of the Executive Committee when we discussed the matter of price of back numbers of the Journal, I send you the following memorandum and recommendation for presentation at the March meeting, since, unfortunately, I shall be in the West at that time and unable to attend the meeting.

Some years ago we established, by vote of the Executive Committee, a series of premium prices on back numbers of the Journal, by which the price of each copy was increased by 15 cents for each year previous to a certain date. This, of course, makes some of the old numbers very high priced, although, as a matter of fact, we have as many of some of the earlier numbers on hand as we have of some of the comparatively recent ones. A couple of years ago it became necessary to give away quite a number of surplus copies of the Journal in order to clear our shelves. At that time, however, we took pains to retain at least twenty-five copies of all the issues of which we had as many as twenty-five to start with.

We now have on hand five or less copies of only four issues, viz.: No. 4, Volume 1, of which the present price is $2.85; No. 2, Volume 2, the price of which is $2.70; No. 4 of Volume 10, price $1.50; No. 4 of Volume 11, price $1.35. On the present schedule of prices the price of a complete set of the Journal to 1907, inclusive, is $125.50.

I now feel that the effect of the present schedule of prices is, to a large extent, to prevent sales, and as each new issue of the Journal makes an addition to our stock and requires additional storage room, I am inclined to feel that it would be wise to fix a price at which we could move the old issues more rapidly. I also feel that we should fix a price for a whole set at which we could more easily place them in public libraries or libraries of scientific schools.

There have been up to date twenty-one complete volumes of the Journal and two issues of Transactions, or twenty-three annual volumes, one of which covers a year and a half and contains six numbers of the Journal (Volume 15).

I recommend that for all sales of an entire set or of early volumes of the Journal required to make up a set for libraries or for individuals, we make a price of $3.00 per volume (except for Volume

15, which contains six numbers, and for which the price should be $4.50), making $70.50 for a full set up to and including 1907; that for single copies of the JOURNAL of which we have more than five copies on hand the price be $1.00 each, and where we have five or less copies, the price be $2.00, irrespective of the date of issue. Also that where we have not more than five copies of an issue on hand, complete volumes containing the issue be sold only by the single number *except* in case of selling a more or less complete set at one time.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

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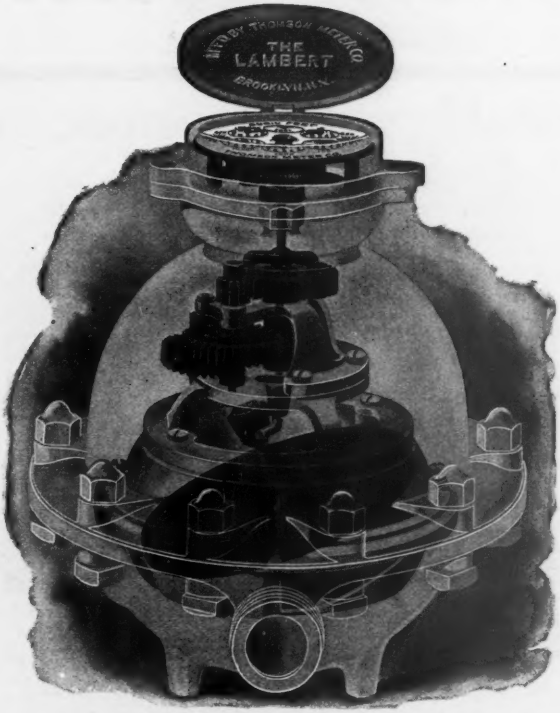

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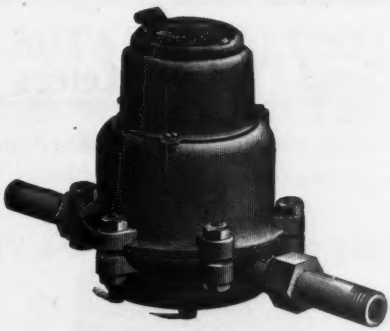

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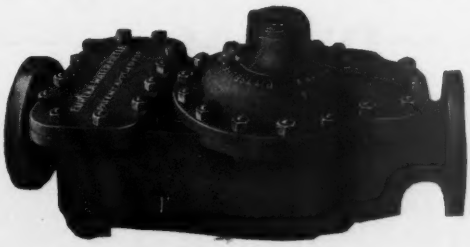

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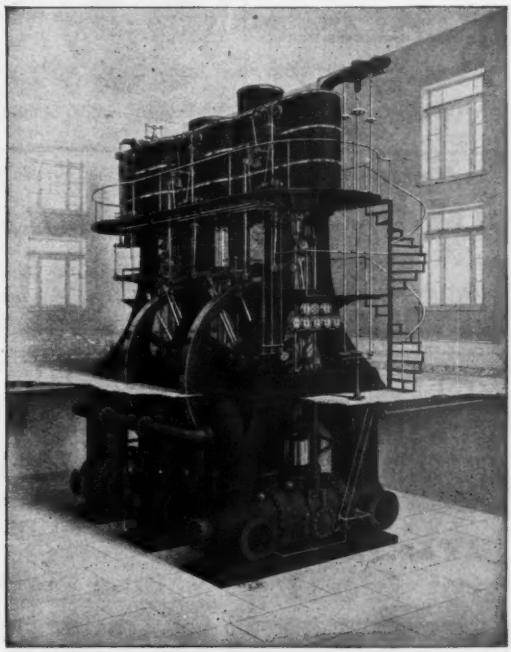

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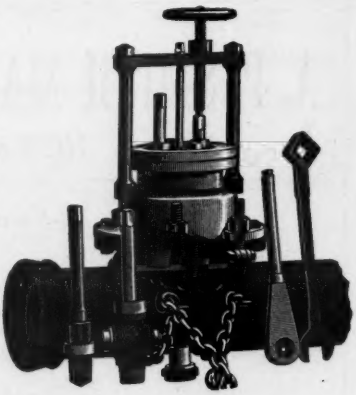

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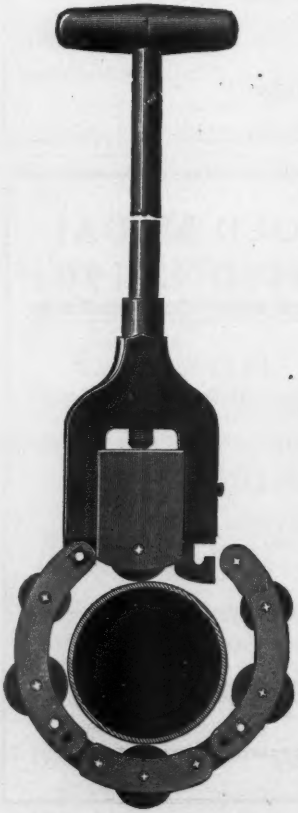

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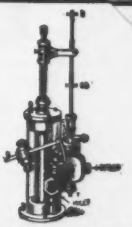

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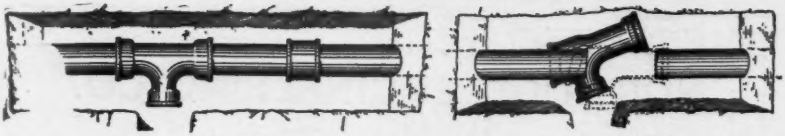

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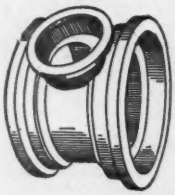

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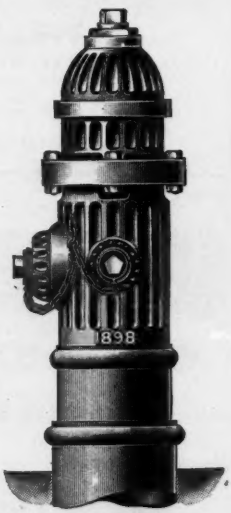

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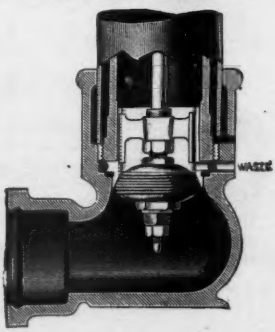

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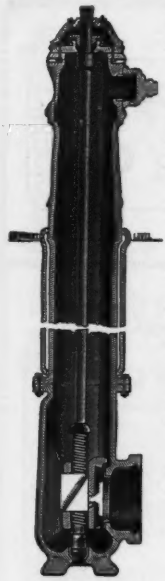

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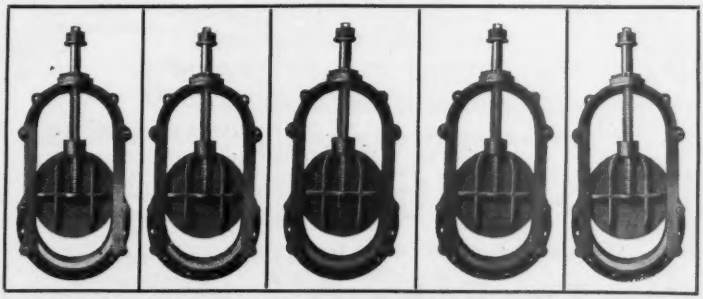

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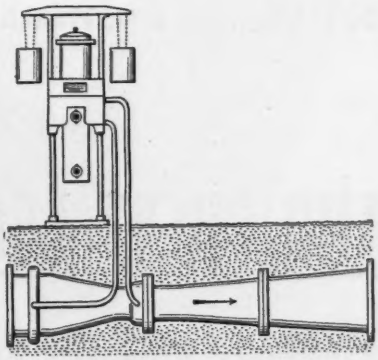

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